JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

FEBRUARY

1956

Volume 15 Number 1

EDITORIAL BOARD

J. K. Loosli, *Editor and Chairman*
W. D. Gallup, *Associate Editor*

O. G. Bentley (1959)*
L. E. Harris (1956)
R. W. Bray (1956)
C. E. Terrill (1957)
A. V. Nalbandov (1957)
A. B. Chapman (1958)
C. F. Huffman (1958)
S. W. Terrill (1958)
L. E. Hanson (1959)

W. M. Beeson, *Business Manager*

* Terms expire on December 31 of years indicated.

OFFICERS OF THE SOCIETY

L. E. Casida, *President*
J. C. Miller, *Vice President*
W. M. Beeson, *Secretary, Treasurer*
N. S. Hale, *North-Atlantic Vice President*
W. P. Garrigus, *Southern Vice President*
F. F. McKenzie, *Western Vice President*
J. I. Miller, *Director*

Reprints of papers published herein are obtainable only from the authors.

Entered as second class matter under act of March 3, 1879, The Journal of Animal Science is published during February, May, August, and November by the Boyd Printing Company, Inc., 372–374 Broadway, Albany 7, N. Y. For Volume 14 (1955) domestic subscription price is $6.00; rest of North and South America is $6.50; and other places $7.00. Send your subscription to the publishers, 372–374 Broadway, Albany 7, New York or to W. M. Beeson, Department of Animal Husbandry, Purdue University, Lafayette, Ind. Make check payable to the American Society of Animal Production. Foreign subscribers please remit by International money order or by a draft on a New York Bank. Notices of change of address should be in the hands of Dr. Beeson 40 days previous to month of issue, to insure prompt delivery. Missing copies, owing to change in address cannot be supplied unless adequate notice has been given. Subscribers or members failing to receive a number of the Journal should notify the Business Manager within 90 days of publishing date. Missing copies will be replaced only if due to error on the part of the Business Manager or printing company.

Journal of
ANIMAL SCIENCE

VOLUME 15 FEBRUARY, 1956 NUMBER 1

CONTENTS

Page

The Influence of Oral Administration of Diethylstilbestrol upon Estrogenic Residues in the Tissues of Beef Catte. R. Preston, E. Cheng, C. D. Story, P. Homeyer, J. Pauls and W. Burroughs 3

Biological Assay of Beef Steer Carcasses for Estrogenic Activity Following the Feeding of Diethylstilbestrol at a Level of 10 Mg. Per Day in the Ration. C. W. Turner 13

The Estrogenic Activity of Alfalfa and other Feedstuffs. P. J. S. Pieterse and F. N. Andrews 25

Further Studies on Anabolic Effect of Stilbestrol in Cattle as Indicated by Carcass Composition. M. T. Clegg and F. D. Carroll 37

Effects of Low Level Implantation of Stilbestrol in Steers on Pasture. C. C. O'Mary and A. E. Cullison 48

Effects of Low Level Implantations of Stilbestrol in Steers Fattened on Dry Lot Rations. C. C. O'Mary, E. P. Warren, T. J. Davis and H. H. Pierce 52

Performance and Grazing Habits of Hereford and Aberdeen Angus Cows and Calves on Improved Pastures as Related to Types of Shade. A. H. McDaniel and C. B. Roark 59

Further Studies on the Utilization of Alfalfa by Beef Steers. J. H. Meyer, G. P. Lofgreen and N. R. Ittner 64

Use of Antipyrine in Nutritional and Meats Studies with Cattle. G. H. Wellington, J. T. Reid, L. J. Bratzler and J. I. Miller 76

The Use of Specific Gravity of Certain Untrimmed Pork Cuts as a Measure of Carcass Value. A. M. Pearson, L. J. Bratzler, R. I. Deans, J. F. Price, J. A. Hoefer, E. P. Reineke and R. W. Luecke 86

Slaughter and Carcass Characteristics of Shortfed Yearling, Hereford, and Brahman × Hereford Steers. O. D. Butler, B. L. Warwick and T. C. Cartwright 93

Extensibility of Single Meef Muscle Fibers. H. Wang, D. M. Doty, F. J. Beard, J. C. Pierce and O. G. Hankins 97

The Influence of Size and Type on Growth and Development of Cattle. J. F. Kidwell and J. A. McCormick 109

A Study of Vaginal and Uterine Prolapse in Hereford Cattle. R. R. Woodward and J. R. Quesenberry 119

A Genetic Analysis of Weaning Weights in a Range Beef Herd Operated Under Optimum and Sub-optimum Nutritional Regimes. W. C. Rollins and K. A. Wagnon 125

Alteration of Ovarian Activity by Hysterectomy. J. N. Wiltbank and L. E. Casida 134

Correlations Between Ambient Temperatures Varying from 60°–95° F. and Certain Physiological Responses in Young Dairy Bulls. R. B. Casady, J. E. Legates and R. M. Myers 141

Page

The Nutritive Value of Various Grasses and Grass-Legume Mixtures. W. E. Watkins and J. V. Kearns, Jr. 153
Grass Silage Preservation with Sodium Metabisulfite. J. W. Bratzler, R. L. Cowan and R. W. Swift 163
The Effects of Injected Testosterone on Adult Ewes. E. F. Johnston, F. Hudson, R. Bogart, A. W. Oliver and F. F. McKenzie 177
Retention of Injected Testosterone in the Meat of Adult Ewes. E. F. Johnston, F. Hudson, R. Bogart and J. Kaufmes 185
Effect of Chlortetracycline, Stilbestrol and Chlortetracycline-Stilbestrol Supplements on Fattening Lambs. P. S. Jordan, R. M. Jordan and H. G. Croom 188
Heritability of Multiple Birth in Sheep. J. Rendel 193
Some Aspects of Twin Versus Single Lambs of Navajo and Navajo Crossbred Ewes. G. M. Sidwell 202
The Effect of Chlortetracycline upon Digestion of Ration Components, Retention of Nitrogen and Volume of Urine Excreted by Sheep with Observations on Rectal Temperatures. A. D. Tillman and R. McVicar 211
Estimation of Clean Fleece Weight from Small Side Samples and From Wool Density, Body Weight, Staple Length and Grease Fleece Weight. G. M. Sidwell, G. L. Jessup, Jr. and W. D. McFadden 218
The Lack of Toxicity of Biuret to Animals. W. T. Berry, Jr., J. K. Riggs and H. O. Kunkel 225
The Glucose Tolerance Test in Swine and Its Implications. I. M. Bunding, M. E. Davenport, Jr., and M. A. Schooley 234
A Genetic Study of Weight at Five Ages in Hampshire Swine. J. V. Craig, H. W. Norton and S. W. Terrill 242
Carcass Yields as Related to Live Hog Probes at Various Weights and Locations. H. O. Hetzer, J. H. Zeller and O. G. Hankins. 257
The Interaction of Temperature and Thiouracil Feeding Upon Carcass Characteristics and Feeding Characteristics of Pigs. E. F. Johnston, N. R. Ellis and C. F. Winchester 271
The Comparative Value of Antibiotics and Arsonic Acids for Growing Pigs. L. E. Hanson, E. G. Hill and E. F. Ferrin ... 280
The Influence of Tryptophan, Methionine and Lysine Supplementation of a Corn-soybean Oil Meal Diet on Nitrogen Balance of Growing Swine. R. J. Meade 288
The Influence of Protein Content of the Diet and of Chlortetracycline and/or Vitamin B_{12} Supplementation Upon Performance of Growing-Fattening Pigs. R. J. Meade 297
Portable Units for Individual Experimental Pig Feeding on Pasture. G. C. Ashton, D. V. Catron, P. G. Homeyer, N. H. Curry and C. C. Culbertson 307
Comparison of Refined Cane Sugar, Invert Cane Molasses and Unrefined Cane Sugar in Starter Rations for Early Weaned Pigs. F. Diaz, V. C. Speer, G. C. Ashton, C. H. Liu and D. V. Catron 315
Proceedings of Annual Meeting 320
Committee Page 337
News & Notes 342

THE INFLUENCE OF ORAL ADMINISTRATION OF DIETHYLSTILBESTROL UPON ESTROGENIC RESIDUES IN THE TISSUES OF BEEF CATTLE

RODNEY PRESTON, EDMUND CHENG, C. D. STORY, PAUL HOMEYER, JOHN PAULS and WISE BURROUGHS

Iowa Agricultural Experiment Station [1]

THE incorporation of diethylstilbestrol (stilbestrol) in beef cattle rations has resulted in increased bodyweight gains, lowered feed requirements per unit of gain and the production of satisfactory beef carcasses as judged by various physical carcass evaluations (Burroughs *et al.*, 1955, and Kastelic *et al.*, 1956). Before this practice of orally administering stilbestrol to cattle could be recommended for general usage it was necessary that the edible and inedible tissues of cattle be examined critically with respect to the presence of estrogenic residues. Experiments have demonstrated small amounts of estrogenic activity in the tissues of cattle given stilbestrol by pellet implantation under the skin (Stob *et al.*, 1954a). Recently Perry *et al.* (1955) have reported no estrogenic residues in the tissues of beef cattle fed synthetic estrogens. The purpose of this paper is to present information upon the presence or absence of estrogenic residues in the tissues following oral administration of stilbestrol to cattle.

Experimental Methods

Two methods were employed in this investigation of beef tissues for estrogenic activity. The first method was a modification of the mouse-uterine-weight technique as employed by Stob *et al.* (1954b). This method consisted of feeding a diet containing high levels of the respective tissue under examination to a group of 9 to 10 intact immature female mice for 10 days. At the end of the 10-day feeding period the mice were sacrificed, the uteri dissected, fixed in Bouin's solution for 24 hours, trimmed and then weighed after the excess solution and moisture had been removed with filter paper. The average weight of the uteri from mice fed a given tissue from cattle which received stilbestrol was then compared with the average uterine weight of mice

[1] Journal paper No. J-2790 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 869.

fed tissue from cattle receiving no stilbestrol. If the average uterine weight from the first group of mice was found to be significantly heavier than that from the second group of mice, then it was concluded that a stilbestrol residue accumulated in the tissue of the stilbestrol-fed cattle. On the other hand, if there was no difference between the mean uterine weights of the two groups of mice, it was assumed that no stilbestrol residue of sufficient magnitude to be measured by this assay method had accumulated. The estimated amount of stilbestrol present in any cattle tissue fed to mice was determined by comparing the mean uterine weight thus obtained to a standard curve obtained by plotting the mean uterine-weight response to known amounts of stilbestrol fed to respective groups of 10 comparable female mice each. The principal difference between this first method of assay and the method of Stob *et al.* (1954b) was the use of immature female mice (Rockland C.F.W. Strain) weighing 8 to 10 gm. initially rather than the use of ovariectomized mature female mice.

The cattle tissues examined were from a series of four experiments with two to four lots of cattle per experiment. The tissues examined consisted of lean muscle, fat, liver, kidney, heart and pooled offal organs including beef tripe, intestinal tract, lungs and spleen. The lean and the fat samples from three of the experiments were obtained from the 12th beef rib section. In the fourth experiment these samples were obtained from the head trimmings. In assaying the various tissues, pooled samples from all of the cattle (between 5 and 10 in number) in a given lot receiving a specific ration were used in all instances rather than samples from individual animals. For example, approximately one pound of lean meat was collected from each of an experimental lot of eight cattle and pooled for assay purposes. This procedure was followed in the case of all other tissues. The visceral organs were washed at the time of collection.

Following the collection of the pooled samples they were frozen, ground, dried at 65° C. for 24 hours and then stored under refrigeration for 2 to 3 weeks. In assaying the tissues, they were incorporated into a mouse diet so that the final mixture contained 80 percent of the dried tissue under study and 20 percent of a basal diet. The fat assay diet consisted of 30 percent fat and 70 percent of a basal diet. The basal diet consisted of a mixture of 74 percent ground yellow corn, 20 percent dried non-fat milk solids, 4 percent corn oil and 2 percent minerals. This mixture was also used as the mouse diet to which the following amounts of stilbestrol were added per gram of diet respec-

tively in establishing the standard uterine-weight-response curve: none, .005, .010 or .020 mcg. During the assay period each mouse consumed an average of 2 gm. of diet daily. The growth rates of the mice fed test diets were satisfactory.

Two groups of experimental cattle (1 and 3) were described in a previous publication (Burroughs *et al.*, 1955). The cattle in Experiment I consisted of four lots of eight yearling steers fed identical fattening rations for 112 days except for different amounts of added stilbestrol. Lot 1 received no stilbestrol while lots 2, 3 and 4 received 2.75, 5.5 and 11.0 mg. daily, respectively per animal. Stilbestrol was removed from the feed five days before slaughter in the belief that possible trace amounts in the tissues might be eliminated before slaughter.

In the second experiment two lots of eight steers each were fed similar fattening rations for 112 days except for their supplementary protein allowance. One lot received 3 lb. of soybean oil meal daily per animal while the second lot received 3 lb. daily per animal of a mixture of supplementary feeds containing 5.5 mg. of stilbestrol. Unlike the previous experiment, the cattle in lot two of this experiment were fed stilbestrol right up to the time they were trucked to market for slaughter.

The third experiment consisted of three lots of eight heifers, each fed a fattening ration for 113 days which was similar in each lot except for the amount of stilbestrol added. Lot 1 received no stilbestrol while lots 2 and 3 received respectively 6 and 12 mg. of stilbestrol daily per animal. Only five animals were slaughtered out of each of these lots since the remainder of the heifers were retained for a breeding performance study. Stilbestrol feeding was discontinued two days prior to slaughter.

In the fourth experiment 2-year-old steers were used. Two lots of nine animals each were fed a fattening ration for 84 days which was similar except for the absence or presence of stilbestrol. Lot 1 served as the control and lot 2 received 9 mg. of stilbestrol daily per animal. The lot 2 cattle were fed stilbestrol right up to the time they were trucked to market for slaughter.

A total of 37 composite tissues from the four cattle experiments were examined using this initial method of assay. Since this first assay method was subject to some criticism in statistically interpreting the reliability of the quantitative estimates of stilbestrol residues in the tissues, it was deemed desirable to use a second assay procedure. This

second procedure consisted of feeding immature intact female white mice, weighing 8 to 10 gm. initially, diets composed of high levels of the tissues. The mice were fed these respective diets for five or seven days, their uteri dissected, fixed in Bouin's solution, trimmed and then weighed after the excess solution and moisture had been removed with filter paper. The amount of tissue incorporated in the diets was 80 percent in the case of dried lean and dried liver and 30 percent in the case of the fat tissue. The preparation of these tissues and their incorporation in the mouse diets were similar to those described in the first assay method.

Rather than re-examine all 37 tissues using the second method of assay, only those tissues were selected which appeared most likely to yield detectable quantities of stilbestrol as indicated by the first assay, if such amounts actually existed. The lean and fat samples selected were from the third cattle experiment, namely the lot three animals receiving 12 mg. of stilbestrol daily in their feed. The liver samples selected were from groups of cattle receiving 5.5 and 10 mg. of stilbestrol per animal daily in their respective feeds. The livers from the 10 mg. cattle were not assayed by the first assay method. The stilbestrol was fed to the cattle right up to the time of trucking which represented 24 to 36 hours prior to slaughter.

In assaying these tissues, each tissue diet was first divided into four equal portions. No stilbestrol was added to the first portion. To the second, third and fourth portions were added .005 mcg., .010 mcg. and .020 mcg. of stilbestrol per gram of diet, respectively. This procedure of adding known amounts of stilbestrol to the tissues under study was necessary because the initial assay procedure had indicated that the quantity of stilbestrol residue in the tissue was either nil or so small as to render it extremely difficult to obtain a reliable estimate of its magnitude. Therefore, these quantities of stilbestrol were added both to the tissues of cattle which had received stilbestrol in their diet and to the tissues of control animals.

Groups of 20 mice in four replicates of five mice each were used for each level of added stilbestrol to a given tissue diet, making a total of 80 mice for each sample of tissue that was assayed. The tissue from cattle which had received stilbestrol in their feed was designated for convenience as "unknown," denoting that the tissue was unknown with respect to the quantity of residual stilbestrol present. The estrogenic response in mice receiving diets composed of an "unknown" tissue was in turn compared with the estrogenic response obtained with diets

containing comparable amounts of added stilbestrol but which were made up with tissue from comparable cattle of a given experiment which had not received stilbestrol in their ration prior to slaughter. These tissues from control lots of cattle were designated "standard" tissues denoting that they were known not to contain stilbestrol residues originating from feed consumed by the cattle. In carrying out this assay, the mean uterine weight of the five mice in a single replicate of any treatment was considered to be a single observation for that treatment.

The measurement of the presence or absence of stilbestrol residue in an "unknown" tissue diet was then made by plotting the estrogenic response curve of measured additions of stilbestrol to this diet, and comparing this response curve to a curve established in the same manner by the "standard" tissue diet. Thus, if stilbestrol residues were present in the "unknown" tissue, the curve established should be different from the curve established using the "standard" tissue. Further, in establishing these curves, the data obtained lend themselves to a more precise statistical analysis than the first assay procedure in determining the quantitative reliability or sensitivity of the assay actually carried out (Homeyer and Pauls, 1955).

Duplicate determinations were carried out using this second method of assay on each of the two liver samples, the lean sample, and the fat sample selected. In the first determination, instead of having 20 female mice in four replicates of five mice each on a given diet as originally planned, it was learned during the progress of the assay that these mice had not been sexed but consisted of both males and females. Accordingly the 20 mice on each given treatment consisted of approximately 10 females rather than double that number. Nevertheless, this first determination was completed with the reduced numbers since it was valuable for comparative purposes with the second determination. The two determinations were carried out just alike except in assay one the mice were fed the test diets for five days, whereas in assay two the diets were fed for seven days.

Results and Discussion

No stilbestrol residues were detected in any of the beef tissues examined using either method of assay. This was true with respect to lean meat, fat, liver, heart, kidney and offal tissues which included beef tripe, intestines, lungs and spleen. The data obtained by using the first assay method are summarized in table 1. The only tissue from

cattle receiving stilbestrol which produced heavier mouse uterine weights than the control cattle tissue diet was the liver in Experiment II, where statistical significance was approached at the P .05 level. On the other hand, two cattle tissues (kidney and fat in Experiment III) from the control cattle receiving no stilbestrol produced significantly heavier mouse uterine weights than comparable tissues from cattle actually receiving stilbestrol in their rations. The explanation

TABLE 1. BEEF TISSUE ASSAYS FOR STILBESTROL RESIDUES

(Method 1)

Experiment 1								
Stilbestrol fed daily (mg.)	None		2.75		5.5		11.0	
Mean mouse uterine wt. (mg.)								
Beef lean tissue diet	(9)[a]	9.2±0.6[b]	(10)	7.2±0.5	(10)	7.5±0.6	(10)	7.7±0.7
Beef liver tissue diet	(9)	4.5±0.2	(9)	4.9±0.2	(10)	4.0±0.2	(9)	4.6±0.2
Beef fat tissue diet	(9)	7.9±1.5	(9)	8.3±1.1	(10)	7.4±0.6	(10)	8.3±0.9
Experiment 2								
Stilbestrol fed daily (mg.)	None		5.5					
Mean mouse uterine wt. (mg.)								
Beef lean tissue diet	(10)	7.7±0.5	(8)	7.8±0.5				
Beef liver tissue diet	(10)	5.3±0.4	(10)	9.1±1.1				
Beef fat tissue diet	(10)	6.5±0.3	(10)	5.8±0.5				
Experiment 3								
Stilbestrol fed daily (mg.)	None		6.0		12.0			
Mean mouse uterine wt. (mg.)								
Beef lean tissue diet	(9)	7.5±1.0	(9)	8.6±1.9	(8)	11.4±1.3		
Beef liver tissue diet	(9)	6.6±0.5	(9)	6.4±0.6	(9)	6.6±0.5		
Beef fat tissue diet	(9)	16.0±1.6	(8)	6.2±0.8	(9)	6.2±1.0		
Beef kidney tissue diet	(8)	13.6±0.8	(9)	9.3±0.9	(9)	11.8±1.2		
Beef heart tissue diet			(10)	9.8±1.0	(10)	8.0±0.8		
Beef offal tissue diet	(9)	7.9±0.8	(9)	6.3±0.8	(9)	8.1±0.8		
Experiment 4								
Stilbestrol fed daily (mg.)	None		9.0					
Mean mouse uterine wt. (mg.)								
Beef lean tissue diet	(10)	4.2±0.4	(8)	3.7±0.2				
Beef fat tissue diet	(9)	8.3±0.6	(10)	5.1±0.4				

[a] Figures in parentheses represent the number of female mice in each group.
[b] Standard error of means.

for these two high values involving tissues from control cattle is not readily apparent.

In assessing the overall significance of the results using this first assay procedure an estimate of the sensitivity of the assay method employed was determined by a study of the uterine-weight-responses obtained in four series of female mice fed known amounts of stilbestrol. These standard uterine weight responses (table 2) were obtained on comparable female mice at the same time the cattle tissues were being assayed.

After submitting the data of table 2 to a statistical analysis (Homeyer

and Pauls, 1955) it was concluded that this bio-assay procedure was sufficiently sensitive to detect as little as .003 mcg. of stilbestrol per gram of diet. When mouse diets were fed containing 80 percent of tissue, this method would be expected to measure as little as $(\frac{100}{80} \times .003) = .004$ mcg. of stilbestrol per gram of dried tissue. Since this tissues was in a dry form in the mouse diet, the comparative figure for fresh tissue containing 66 percent moisture would be .0014 mcg. of stilbestrol per gm. of fresh tissue. Another way of expressing this same relationship is that the bio-assay procedure employed in testing the experimental beef tissues (excluding the fat) was sufficiently sensitive to detect as little as 1.4 parts of stilbestrol per billion parts of tissue,

TABLE 2. STANDARD UTERINE WEIGHT RESPONSE TO STILBESTROL FED TO IMMATURE FEMALE MICE

Trial number	Mcg. diethylstilbestrol per gm. mouse diet			
	None	.005	.010	.020
	Mean uterine weight in mg.			
1	(10)[a] 4.4±1.3[b]	(8) 13.4±7.0	(10) 27.9±9.4	(9) 40.0± 8.5
2	(10) 8.0±1.5	(8) 12.2±2.7	(10) 17.7±6.5	(10) 33.2±11.5
3	(10) 6.6±1.8	(10) 12.2±3.4	(10) 20.4±5.7	(10) 36.1± 9.0
4	(9) 7.1±0.8	(9) 19.9±4.1	(9) 30.8±6.4	(9) 43.2± 6.5

[a] Figures in parentheses represent the number of female mice in each group.
[b] Standard error of means.

or 1.4 mcg. per kg. In the case of the fat tissue which was incorporated into the mouse diet at a lower level (30 percent) the comparative sensitivity of this method would be 3 parts of stilbestrol per billion parts of fat.

The results of the second mehtod of assay were similar to those of the first indicating no residual estrogenic activity in the meat tissues examined. This was true in both repetitions. The average uterine weights for the second method of assay are presented in table 3.

Upon submitting these data to statistical analysis (Homeyer and Pauls, 1955) it was estimated that in the first determination the "unknown" lean meat diet contained .0001 mcg. more of stilbestrol activity than the "standard" per gram of mouse diet. In the second determination, the comparable estimated difference was .0006 mcg. In order for these estimates to be judged significantly different from zero (P .05) they would have needed to be .0014 and .0012 mcg. of stil-

TABLE 3. BEEF TISSUE ASSAYS FOR STILBESTROL RESIDUES (Method 2)

Tissue examined	"Standard" tissue				"Unknown" tissue			
Stb. added (mcg./gm. mouse diet)	0	.005	0.01	.020	0	.005	.010	.020
	Mean uterine weights in mg.				Mean uterine weights in mg.			
Beef lean tissue diet								
First determination [a]	6.1±0.4 [c]	9.0±0.4	13.9±0.5	26.3±1.1	6.6±0.7	8.8±0.6	14.0±0.7	26.9±1.6
Second determination [b]	7.6±0.2	10.2±0.3	13.8±0.4	26.4±0.9	7.6±0.2	9.4±0.2	14.6±1.3	24.7±0.5
Beef fat tissue diet								
First determination [a]	5.7±0.2	9.7±0.7	19.0±2.4	29.9±1.3	4.9±0.4	8.4±0.9	15.4±1.3	23.3±5.8
Second determination [b]	6.9±0.7	11.1±0.4	19.3±1.7	41.1±5.4	6.5±0.5	10.9±1.4	19.9±0.7	40.0±7.7
Beef liver tissue diet								
First determination [a]	5.7±0.2	7.9±0.1	13.9±1.5	20.7±1.0	7.0±0.5	8.8±0.2	13.2±0.8	22.0±1.5
Second determination [b]	6.4±0.4	12.5±0.4	20.7±0.8	31.2±2.0	7.1±0.1	14.1±0.5	21.2±1.2	31.1±3.4

[a] Approximately ten mice were used for each level of added stilbestrol in four replicates.
[b] Twenty mice were used for each level of added stilbestrol in four replicates.
[c] Standard error of the means.

bestrol per gram of diet in the first and second determination respectively.

The estimated differences obtained with the fat diets were —.0032 mcg. in the first determination (that is, the "standard" apparently had more estrogenic activity than the "unknown" diet) and .001 mcg. of stilbestrol per gram of diet in the second determination. In order for these estimates to be judged significantly different from zero (P .05), they would have needed to be .0039 mcg. of stilbestrol per gram of diet in each determination.

Similarly in the case of the liver tissues the estimated differences in "standard" and unknown diets were .0009 mcg. in the first determination and .0006 mcg. of stilbestrol per gram of diet in the second determination. In order for these estimates to be judged significantly different from zero at the P .05 level, they would have needed to be .0019 and .0029 mcg. of stilbestrol per gram of diet in the first and second determinations, respectively.

It seems fair to conclude that there was no detectable stilbestrol residue in the lean, fat and liver samples tested using this second method of assay. The precision of this method of assay was approximately similar to that of the first method of assay. If stilbestrol residues had been present in the fresh beef tissues in as small an amount as two parts per billion they would have been detected as statistically significant on the basis of the average sensitivity of this method of assay. Somewhat higher precision was noted in the assays with lean and liver tissues than with fat tissues; however, the precision in all cases was satisfactory.

Summary

Examination of tissues removed from cattle fed diethylstilbestrol in four experiments revealed no detectable estrogenic residues in the lean, fat, liver, heart and kidney tissues as well as the pooled offal organs which included tripe, intestines, lungs and spleen. Estrogenic residues were checked using two mouse-uterine weight assay techniques. The average sensitivity of both methods was such that if as little as 2 mcg. of stilbestrol per kg. of tissue had been present it would have been detected.

Literature Cited

Burroughs, Wise, C. C. Culbertson, Edmund Cheng, W. H. Hale and Paul Homeyer. 1955. The influence of oral administration of diethylstilbestrol to beef cattle. JOURNAL OF ANIMAL SCIENCE 14:1015.

Homeyer, Paul and John Pauls. 1955. Unpublished data.

Kastelic, J., Paul Homeyer and E. A. Kline. 1956. The influence or oral administration of diethylstilbestrol on certain carcass characteristics of beef cattle. In press.

Perry, T. W., W. M. Beeson, F. N. Andrews and Martin Stob. 1955. The effect of oral administration of hormones on growth rate and deposition in the carcass of fattening steers. JOURNAL OF ANIMAL SCIENCE 14:329.

Stob, Martin, F. N. Andrews, M. X. Zarrow and W. M. Beeson. 1954a. Estrogenic activity of the meat of cattle, sheep and poultry following treatment with synthetic estrogens and progesterone. JOURNAL OF ANIMAL SCIENCE 13:138.

Stob, Martin, F. N. Andrews and M. X. Zarrow. 1954b. The detection of residual hormone in the meat of animals treated with synthetic estrogens. Am. Jour. Vet. Res. 15:319.

BIOLOGICAL ASSAY OF BEEF STEER CARCASSES FOR ESTROGENIC ACTIVITY FOLLOWING THE FEEDING OF DIETHYLSTILBESTROL AT A LEVEL OF 10 MG. PER DAY IN THE RATION [1]

CHAS. W. TURNER

Missouri Agricultural Experiment Station [2]

IN the use of natural or synthetic estrogens, either as subcutaneous implants of pellets or as orally administered hormone as an integral part of the feed, to stimulate increased growth rate of beef cattle, the problem of possible estrogen residues in the edible tissues is of imporance from a public health standpoint. It is of importance also to the fur animal industry since some of the inedible tissues are utilized in the rations of fur animals.

The earlier reports concerned estrogen residues in poultry tissue (Bird *et al.*, 1947; Gowe, 1949; Greenblott and Brown, 1952; Jones and Deatherage, 1953; and Swift, 1954). Since the amounts of estrogen administered to birds in relation to their body weight are greatly in excess of the optimal amounts administered to cattle these reports are not applicable to the present problem.

Two methods have been used in the study of tissue estrogen. Several investigators have extracted the tissues with suitable solvents and then biologically assayed the extracts or measured the estrogen by chemical and physical methods (Bird *et al.*, 1947; Gowe, 1949; Jones and Deatherage, 1953; and Swift, 1954). The presence of both free and combined estrogen in the tissues raises questions as to the completeness of the extraction procedures.

The biological assay of estrogens using mice as assay animals has been adapted in several recent investigations. Both immature (about 21 days old) and older ovariectomized mice have been shown to be extremely sensitive to estrogens using the increasing weight of the uterus as an index (Stob *et al.*, 1954; Burroughs *et al.*, 1954).

Since the biological methods of assay of estrogen have been shown to

[1] This study was aided by a grant from the National Live Stock and Meat Board.
Contribution from the Department of Dairy Husbandry, Mo. Agr. Exper. Sta. Journal Series No. 1544. Approved by the Director.

[2] Columbia.

be very sensitive to added estrogen this method was used in the study to be reported following the method described by Stob *et al.* (1954).

In the assay of muscle (70 percent lean and 30 percent fat) and liver from cattle pelleted with varying amounts of synthetic estrogens, Stob *et al.*, (1954) observed evidence of slight amounts of residual estrogens. In later trials with orally administered estrogen, no residual hormone was detected whether the estrogen was fed up to the time of slaughter or discontinued 7-days earlier (Perry *et al.*, 1954). Burroughs *et al.* (1954) reported that edible and inedible cattle tissues revealed no detectible stilbestrol residues provided the 10 mg. level of stilbestrol feed was removed from the ration 48 hours before slaughter. Chas. Pfizer & Co. reported that their tests have indicated that the lean meat and fat of steers fed diethylstilbestrol at the 10 mg. level daily are essentially devoid of residual estrogenic activity. The assays showed that these tissues did not contain more than two parts per billion of diethylstilbestrol activity, this level being the sensitivity of the test (Pfizer, 1955). No details of the assays have been reported.

The object of this report is to present data on the bioassay of residual estrogen in the tissues of groups of steers fed diethylstilbestrol at the 10 mg. daily level in comparison with the same tissues from a control group of steers. Not only were the edible tissues and organs assayed but also included were samples of the other glands and organs, digestive tract, and blood.

Experimental Procedures

Source of Tissues Assayed

The animals available for this study consisted of three groups of Hereford steers including 10 control animals and two lots of 10 steers, each of which had received 10 mg. of diethylstilbestrol daily during a feeding period of 148 days.[3] The diethylstilbestrol was removed from the ration about 44 hours prior to slaughter at the Wilson & Co. plant at Kansas City.[4] The writer was present and supervised the collection of the various samples assayed except the rib-eyes which were obtained later after cooling the carcasses.

The samples from the control animals represent a composite of each tissue from each of the 10 animals whereas the samples from the

[3] The Columbian Hog & Cattle Powder Co. of Kansas City, Mo. kindly made the cattle available from their feed lots.

[4] Thanks are due the management of the Wilson & Co. plant in Kansas City for aiding in obtaining samples of the carcasses used in this study.

diethylstilbestrol-fed steers represents a composite from each tissue of the 20 animals.

These samples were brought intact to our laboratory, run through a meat grinder and thoroughly mixed. To each sample of fresh tissue was added 10 percent of the normal mouse ration. The samples were then packeted in amounts required for the daily ration of 10 mice. These packets were placed in the deep-freeze until they were fed. The mice received the daily ration directly from the freezer without thawing the meat.

In the assay of the fat samples, two levels of feeding were tried. At the 25 percent fat level, the residue of the ration consisted of 75 percent mouse feed. At the 50 percent fat level, the ration included equal parts of commercial casein and mouse feed.

Method of Bioassay of Tissues

The mice used in the assay were ovariectomized and the uterus allowed to involute for a period of 10 days. During this period the animals were fed laboratory mouse feed. The animals were then placed upon the meat samples containing 10 percent of the mouse ration. The animals were fed for 10 days, then sacrificed, body weight determined and the uterus dissected clear of fat and tissue and weighed immediately upon a Roller-Smith balance. Care was taken in dissection to cut the uterus cleanly at the vaginal end of the cervix.

It will be noted that the method of assay of the samples follows, in general, the method suggested by Stob *et al.* (1954). The following modifications were made: 1. Younger mice were used. 2. A period of 10 days was substituted for a period of 3 to 5 weeks for the involution of the uterus. 3. The tissues were frozen instead of dried.

Addition of Diethylstilbestrol to Rib-eye Tissue. To determine the effect of the addition of graded doses of diethylstilbestrol upon the uterine weight, groups of ovariectomized mice were prepared as previously reported. The control rib-eye tissue was ground and to each gram of tissue 0.002 mcg., 0.004 mcg., 0.006 mcg., and 0.008 mcg. diethylstilbestrol was added in an olive oil carrier. The addition of diethylstilbestrol at the 0.002 mcg. per gm. of tissue represents the effect of 2 parts per billion of tissue. The results are shown in table 1.

In the lot fed 0.002 mcg. per gm. of diethylstilbestrol, one mouse whose uterus weighed 22.8 mg. was excluded from the average presented above. When included, the average uterine weight was 13.1. None of

TABLE 1. EFFECT OF GRADED DOSES OF DIETHYLSTILBESTROL ADDED TO CONTROL RIB-EYE TISSUE
(Ovariectomized Young Mature Mice)

Amount of diethylstilbestrol mcg./gm. tissue	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
		gm.	mg.	
Control	10	22.1	9.7	0.044
0.002	8 (9)	21.1	11.9	0.056
0.004	10	21.2	13.4	0.063
0.006	10	21.2	15.6	0.078
0.008	10	18.9	19.9	0.106

the mice in the 0.004 mcg. lot had uteri weighing as much as 20 mg. It will be observed that a regular graded response occurred as the amount of added diethylstilbestrol increased.

Use of Non-ovariectomized Weanling Mice in Assay. Since weanling mice without ovariectomy have also been used as assay animals, it seemed desirable to study their response to graded amounts of diethylstilbestrol added to control rib-eye meat compared to that shown in table 1. The results of this assay are presented in table 2.

It will be noted that there was a graded response in uterine weight as the diethylstilbestrol added to the meat was increased. However, the control group fed commercial mouse feed had uteria larger than any group fed diethylstilbestrol. This confirms the observation of Stob *et al.*, (1954) who stated that the all grain ration fed the mice increased the uterine weight over the groups fed meat. However, the control

TABLE 2. EFFECT OF GRADED DOSES OF DIETHYLSTILBESTROL ADDED TO CONTROL RIB-EYE TISSUE
(Non-ovariectomized Weanling Mice)

Amount of diethylstilbestrol mcg./gm. tissue	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
		gm.	mg.	
Control (mouse feed)	10	19.4	16.4	0.086
Control (Rib-eye)	11	14.7	12.0	0.081
0.002	10	14.8	9.0	0.063
0.004	8	15.5	11.4	0.074
0.006	10	13.5	13.5	0.100
0.008	12	15.6	14.3	0.091

group fed rib-eye tissue had average uterine weights greater than the two lower levels of added diethylstilbestrol.

From the data obtained by feeding graded amounts of diethylstilbestrol to weanling mice and older ovariectomized mice, it would appear that ovariectomized mice are slightly more satisfactory as assay animals. In the present study ovariectomized mice were used exclusively in the assay of all tissue samples.

The Tissue Assayed for Residual Estrogen

Primary interest in the study was naturally the possible presence of residual estrogen in the tissues used for human consumption. The following edible meat samples were assayed: (1), rib-eye; (2), neck trimmings; (3), tip of the tongue; (4), liver; (5), kidney; (6), spleen; (7), heart; (8), lungs and (9), brain.

Some of these samples contained variable amounts of fat. Since studies with poultry showed a tendency for estrogen to collect in the fat, assays were conducted on three types of pure fat, namely, cod, caul and kidney at both 25 and 50 percent levels.

Parts of the digestive tract are, in some cases, used for human consumption and the residue is frequently included in rations prepared for fur animals. The digestive tract is in direct contact with orally administered diethylstilbestrol. The hormone absorbed into the blood must pass through these tissues. The samples included were: (1), rumen and reticulum; (2), omasum; (3), abomasum (true stomach); (4), small intestine; and (5), large intestine. The samples were washed free of digestive contents and composited. The rumen tissue was not processed as is normally done in preparation for human consumption.

The blood carries the hormone to the tissues. However, the diethylstilbestrol containing feed was withdrawn 44 hours prior to slaughter. Blood was assayed similar to the method employed with the tissues.

Results

Results of the Assays

In the interpretation of the results of the bioassays of each tissue, two comparisons are possible. The average uterine weights of the mice fed the tissue from the control steers may be compared with the uterine weights of the mice fed the tissue from the stilbestrol-fed steers. The results of these two assays may then be compared with the bioassay of the rib-eye meat to which graded amounts of stilbestrol were added. The results of the assays are shown in table 3.

TABLE 3. SUMMARY OF THE ASSAY OF TISSUES OF DIETHYLSTILBESTROL-FED STEERS COMPARED TO CONTROL ANIMALS

Type of tissue	Treatment of cattle	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
			gm.	mg.	
		Edible red meat			
Rib-Eye	Control	10	22.1	9.7	0.044
	Stilbestrol	10	24.5	11.4	0.047
Neck Trimmings	Control	10	18.0	7.9	0.043
	Stilbestrol	10	21.5	9.3	0.044
Tongue	Control	9	19.2	9.0	0.048
	Stilbestrol	10	18.5	8.4	0.046
		Glands and organs			
Liver	Control	10	21.6	8.4	0.040
	Stilbestrol	10	21.0	11.5	0.055
Kidney	Control	10	19.0	10.9	0.059
	Stilbestrol	9	21.0	13.3	0.064
Heart	Control	11	18.7	12.4	0.069
	Stilbestrol	10	17.0	11.2	0.069
Spleen	Control	10	19.2	9.9	0.052
	Stilbestrol	10	16.9	12.5	0.074
Lungs	Control	5	15.0	11.5	0.077
	Stilbestrol	9	13.3	24.6	0.190
Brain	Control	6	16.6	8.4	0.050
	Stilbestrol	7	15.8	10.5	0.066
		Depot fat			
25% Kidney Fat	Control	9	22.8	11.8	0.052
	Stilbestrol	9	21.8	9.8	0.046
50% Kidney Fat	Control	9	22.5	8.3	0.037
	Stilbestrol	9	20.9	9.2	0.045
25% Caul Fat	Control	9	19.8	9.3	0.049
	Stilbestrol	9	19.0	8.5	0.046
50% Caul Fat	Control	10	19.1	9.3	0.043
	Stilbestrol	10	19.9	9.0	0.047
25% Cod Fat	Control	9	22.4	10.3	0.047
	Stilbestrol	9	20.0	12.0	0.059
50% Cod Fat	Control	8	19.8	8.0	0.040
	Stilbestrol	9	25.6	10.1	0.039
		Blood			
Blood	Control	9	17.6	9.4	0.054
	Stilbestrol	9	15.1	8.2	0.054
		Digestive tract			
Rumen	Control	9	22.6	9.8	0.046
	Stilbestrol	10	21.2	12.6	0.060

TABLE 3.—Continued

Type of tissue	Treatment of cattle	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
			gm.	mg.	
Omasum	Control	10	21.4	10.1	0.048
	Stilbestrol	10	22.5	11.7	0.053
Abomasum	Control	9	17.1	12.2	0.073
	Stilbestrol	8	16.9	10.6	0.060
Small Intestine	Control	10	19.1	10.9	0.058
	Stilbestrol	11	16.9	10.7	0.061
Large Intestine	Control	7	19.9	10.1	0.051
	Stilbestrol	9	18.3	11.9	0.065

Edible Red Meat. By either of the two comparisons, the rib-eye, neck trimmings and tongue may be said to be free of residual estrogen. This is of great importance since these assays should represent the greater proportion of the salable carcass.

Edible Glands and Organs. The various glands and organs also appear to be free of residual estrogen with two possible exceptions, the kidneys and the lungs. The group of mice fed the kidneys from the stilbestrol-fed steers showed evidence of estrogen equivalent to four parts per billion of tissue. The group of mice fed the experimental lung tissue had an average uterine weight of 24.6 mg. It has been estimated to indicate the presence of about 10 to 12 parts per billion of the tissue. Since the uterine weights of the individual animals showed fairly uniform enlargement, the results do not appear accidental.

Since the kidney is the pathway of excretion of some diethylstilbestrol, it might not be surprising that this tissue should show traces of the hormone. The apparent presence of the hormone in the lungs is rather surprising and unexplainable. Further assays of lungs from stilbestrol-fed cattle should be conducted to determine whether this observation can be confirmed.

Depot Fat. The assay of three types of depot fat at both the 25 and 50 percent levels showed no evidence of residual estrogen.

Blood. The blood showed no evidence of estrogenic activity.

Digestive Tract. The assay of the tissues of the various parts of the digestive tract showed no evidence of stilbestrol even though the feces (even after 44 hours of withdrawal) probably contained appreciable amounts of hormone.

Effect of Diethylstilbestrol on Steer Teat Growth

The natural and synthetic estrogens have a primary role in stimulating the secondary sex tissues of mammals. Teat and mammary gland growth of all mammals studied have been shown to be directly influenced by the estrogens in both sexes (Turner, 1939). The influence of diethylstilbestrol upon the teat and gland development of sheep and cattle of normal males and females as well as gonadectomized animals has been presented graphically by means of udder sections by Wallace (1953). In addition, diethylstilbestrol has been reported frequently to cause elevation of the tail head and some relaxation of the lumbar vertebrae (Perry *et al.*, 1954). The seminal vesicles of steers were

TABLE 4. EFFECT OF ORAL ADMINISTRATION OF DIETHYLSTILBESTROL TO HEREFORD STEERS ON GROWTH OF TEATS

	10 steers		10 steers		10 steers	
	Lot A—Controls		Lot B—Diethylstilbestrol		Lot C—Diethylstilbestrol	
Teat position	Teat length average	Range	Teat length average	Range	Teat length average	Range
	mm.	mm.	mm.	mm.	mm.	mm.
Left front	13.8	4–26	25.6	9–45	26.0	16–36
Right front	14.1	5–28	28.6	18–50	24.1	18–32
Left rear	8.8	3–20	22.8	8–48	23.7	15–31
Right rear	11.2	5–25	24.4	6–43	25.0	17–32
Average	12.0		25.4		24.7	

increased in size and had the appearance of secretory activity (Clegg and Carroll, 1954).

Since the steers in the present study were not fed under the personal supervision of the writer, it seemed of interest to examine the teats and mammary glands of the animals for evidence of diethylstilbestrol stimulation. The gland area of each animal was removed at the time of slaughter and brought to our laboratory for examination and measurement. The length of each teat was measured. The average length of the teats of the control steers (Lot A) was 12.0 mm., whereas the average length of the two lots of steers fed diethylstilbestrol (Lots B and C) were 25.4 and 24.7 mm. respectively, or more than double as long (table 4).

Each teat was injected with a dye solution to note the extent of internal development. In many of the experimental animals, secretory fluid (colostrum) was present in the cistern system which was milked out before the injection was made. It is thus clear that the diethylstilbestrol treatment which these animals underwent during the feeding

period of 148 days caused growth of the teats and duct systems and the secretion of colostrum.

From these observations, it might be suggested that steers showing enlarged teats might be presumed to have been fed diethylstilbestrol.

Bioassay of the Feed Samples

Samples of the grain mixture fed to each lot of steers were obtained. These samples were fed to assay mice as their sole source of nutrients.

It will be seen that marked stimulation of the uterus occurred on the stilbestrol feed (Lots B and C) which was mixed to contain 5 mg. of diethylstilbestrol per pound (table 5). A sample of a commercial

TABLE 5. BIOASSAY OF FEED SAMPLES FED STEERS

Feed	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
		gm.	mg.	
Control Feed (A)	8	17.8	31.5	0.17
Stilbestrol feed (B and C)	7	13.6	61.3	0.45
Commercial stilbestrol feed	9	16.0	76.1	0.48

mixed feed assayed at the same time showed even more marked uterine stimulation but about the same uterine-body weight relation. The sample of control feed gave an unexpected high degree of stimulation. It is well known that soybean oil meal contains plant estrogens. This may account for the stimulation observed in the control feed.

Bioassay of Dried Cattle Feces

While it was not possible to collect feces from the beef cattle in this experiment, it was thought of interest to bioassay the feces of dairy cattle fed diethylstilbestrol at the same level, namely, 10 mg. per day. The feces were collected, dried, ground and mixed with control rib-eye meat at a ratio of 50 percent dried feces to 50 percent fresh meat on a weight basis. This mixture was packeted and frozen similar to the other samples.

The bioassay of the feces from the cow fed the control ration indicated an absence of estrogen whereas the feces of the two cows fed stilbestrol showed concentrations of estrogen about equal to the estrogen in the feed (table 6). Actually, the estrogen content of the feces would be higher than the feed since the feed was fed as the only feed while the feces samples contain 50 percent fresh meat.

Discussion

Of the 21 bioassays of tissues from the control steers there was a variation in mean uterine weight of the mice from a low of 7.9 mg. for neck trimmings to a high of 12.4 mg. for the heart. The average of the means of all control tissues was 9.9 mg. uterine weight. Aside from the assay of the lungs of 24.6 mg., the highest assay of any tissue from the stilbestrol-fed steers was 13.3 mg. for the kidneys and the lowest 8.2 mg. for the blood and 8.4 mg. for the tongue. The average of the means of all tissues of stilbestrol-fed steers was 11.3 mg. If the assay of the lungs is omitted the average of the means is reduced to 10.6 mg. All of the tissues from the stilbestrol-fed cattle with the exception of the lungs and kidneys were within the range of the assays of the control tissues.

TABLE 6. BIOASSAY OF DRIED CATTLE FECES

Cow No.	Feces from	No. of mice	Mean body weight	Mean uterine weight	Uterine weight (% body weight)
			gm.	mg.	
310	Control feed	9	16.0	8.6	0.054
310	Stilbestrol feed	6	17.0	81.7	0.480
585	Stilbestrol feed	10	15.1	60.0	0.404

On the basis of comparison of the tissues from the two groups of steers, it will be noted that the stilbestrol-fed animals stimulated an average of 0.7 mg. more uterine weight (lungs excluded). On this basis of comparison it would appear that little if any residual estrogen was present in the tissues of the stilbestrol-fed steers.

It is possible also to compare the bioassay data with the results obtained when graded amounts of diethylstilbestrol were added to the rib-eye tissue. The average of the control rib-eye tissue was 9.7 mg. which is 0.2 mg. lower than the average bioassay of all control tissues (9.9 mg.). The addition of 2 parts per billion of stilbestrol increased the average uterine weight to 11.9 mg. and 4 parts per billion to 13.4 mg. On the basis of this comparison, the following tissues may have contained the equivalent of 2 parts per billion of stilbestrol: kidney (13.3 mg.), spleen (12.5 mg.), rumen (12.6 mg.), abomasum (12.2 mg.), large intestine (11.9 mg.) 25 percent cod fat (12.0 mg.); and of control animals, heart (12.4 mg.). Only the kidney approached the 4 parts per billion level while the lung tissue contained an estimated 10 to 12 parts per billion.

It is self evident, on the basis of either comparison, that the tissues of these steers fed diethylstilbestrol at the level of 10 mg. per day with withdrawal 44 hours before slaughter either contained no biologically detectable residual estrogen or an amount not exceeding 2 parts per billion. The one tissue which showed an amount of estrogen in excess of the above was the lungs. If further research confirms the observation of residual estrogen in the lungs, the explanation should be sought.

This study reconfirmed the many previous studies which indicate that one of the primary roles of estrogen is the stimulation of the growth of the teats and the duct system of the mammary gland. Evidence of colostrum secretion was present in many of the cisterns of the glands. In the present study the teats of the stilbestrol-fed steers were about double the length of the control animals.

Bioassay of the feed samples fed the two groups of steers indicated the presence of estrogenic activity in both. The estrogenic activity in the control sample was higher than expected although it is known that soybean oil meal contains plant estrogens. A sample of commercial feed tagged to contain 0.0011 percent diethylstilbestrol showed a slightly greater uterine weight stimulation.

The feces of dairy cattle fed 10 mg. of diethylstilbestrol daily when bioassayed produced uterine weights of the same order as of the cattle feed even though it was fed with 50 percent fresh rib-eye tissue.

Summary

A control lot of 10 Hereford steers and a lot of 20 animals receiving 10 mg. daily of diethylstilbestrol were fed for 148 days. The diethylstilbestrol was withdrawn 44 hours before slaughter. Composite samples of 21 tissues, organs, depot fat, digestive tract and blood from the two groups were obtained for bioassay for residual estrogen.

A comparison was made to determine the effect of graded doses of diethylstilbestrol added to control rib-eye tissue using as assay animals young sexually mature ovariectomized mice with normal weanling mice. The sensitivity of the assay method was about 2 parts per billion. Ovariectomized mice were used in all assays.

Using the comparison of the uterine stimulation induced by the control and experimental tissues and by the effect of added diethylstilbestrol, it was concluded that the edible red meat, rib-eye, neck trimmings and tongue did not contain detectable residual estrogen. The liver, heart, spleen, and brain also did not contain detectable amounts of hormone. The kidneys showed evidence of estrogen to the extent of 4 parts per billion while the lungs indicated the presence of 10 to

12 parts per billion of residual estrogen. The depot fat at 25 and 50 percent levels and the blood showed no evidence of estrogen nor did the various parts of the digestive tract.

The average length of the teats of the diethylstilbestrol-fed steers were about double the length of the controls and small amounts of colostrum was frequently observed in the cisterns.

The feed fed the steers was bioassayed. The control feed showed some estrogen activity but the feed containing 5 mg. per pound and a commercial feed caused great uterine stimulation.

Dairy cows fed diethylstilbestrol at the 10 mg. level showed as much estrogenic activity in the dried feces as was present in the feed.

Literature Cited

Bird, S., L. I. Pugsley and M. O. Klotz. 1947. The quantitative recovery of synthetic estrogens from tissues of birds (gallus Domesticus), the response of the birds' testis, comb and epidermis to estrogen and of humans to ingestion of tissues from treated birds. Endocr. 41:282–294.

Burroughs, W. 1955. Tissue examination of cattle fed stilbestrol at the Iowa Station. Meat Conference Concerning Stilbestrol-Fed Cattle. Iowa State College, Ames, Iowa.

Burroughs, W., C. C. Culbertson, J. Kastelic, W. Cheng and W. H. Hale. 1954. Oral administration of diethylstilbestrol for growth and fattening in beef cattle. JOURNAL OF ANIMAL SCIENCE 13:978.

Clegg, M. T. and F. D. Carroll. 1954. Further studies on the anabolic effects of stilbestrol in steers as indicated by carcass composition. JOURNAL OF ANIMAL SCIENCE 13:968

Gowe, R. S. 1949. Residual estrogens in the tissues of fowl treated with dienestrol diacetate. Poultry Sci. 28:666.

Greenblatt, R. B. and N. H. Brown. 1952. The storage of estrogens in human fat after estrogen administration. Amer. Jour. Obst. Gynec. 63:1361.

Jones, O. and F. E. Deatherage. 1953. The diethylstilbestrol content of the meat from chickens treated with this estrogenic substance. Food Research 18:30.

Perry, T. W., W. M. Beeson, F. N. Andrews and M. Stob. 1954. The effect of oral administration of hormones on growth rate and deposition in the carcass of fattening steers. Purdue Univ. Mimeo A. H.

Pfizer. 1955. Oral diethylstilbestrol and diethylstilbestrol with terramycin. Pfizer Agr. Dev. Tech. Bul. 22.

Stob, M., F. N. Andrews and M. X. Zarrow. 1954. The detection of residual hormone in the meat of animals treated with synthetic estrogens. Am. Jour. Vet. Res. 15:319.

Stob, M., F. N. Andrews, M. X. Zarrow and W. M. Beeson. 1954. Estrogenic activity of the meat of cattle, sheep, and poultry following treatment with synthetic estrogens and progesterone. JOURNAL OF ANIMAL SCIENCE 13:138.

Swift, C. E. 1954. The diethylstilbestrol content of tissues of treated steers, lambs, and poultry. Food Res. 19:402.

Turner, C. W. 1939. The mammary glands. Chapt. XI. Sex and Internal Secretions. Second Ed.

Wallace, C. 1953. Observations on mammary development in calves and lambs. Jour. Agr. Sci. 43:413.

THE ESTROGENIC ACTIVITY OF ALFALFA AND OTHER FEEDSTUFFS [1]

P. J. S. Pieterse and F. N. Andrews

Purdue University Agricultural Experimental Station

SINCE the demonstration of estrogenic activity in the inflorescence and peduncles of the female willow (Loewe and Spohr, 1926) approximately 50 species of plants have been shown to possess varying degrees of estrogenic activity. In subterranean clover in Western Australia the estrogenic content was sufficient to adversely affect the reproductive performance of grazing ewes and to cause genital and mammary stimulation in wethers (Bennetts *et al.*, 1946). Because of the increasing use of estrogens in livestock production (Lorenz, 1945; Andrews *et al.*, 1949 and Burroughs *et al.*, 1954) it is desirable to determine the estrogenic activity of common livestock feedstuffs, and to attempt to assess their possible effects on the physiology of animals which consume them.

Materials and Methods

With the exception of some legume and grass samples obtained from commercial dehydrators [2] and the samples of sun cured hay, all legumes and grasses were placed in a plant dryer at 170° F. immediately after harvesting and dried for 24 to 48 hours to a moisture content of 6 to 9 percent. The same procedure was used for feed grains. The dried plant materials were ground in a Wiley mill and 350 gm. of each material was then placed in 1,400 ml. of 95 percent ethanol and refluxed for one hour. The alcohol was cooled, removed by filtration, and the material refluxed for an additional hour in 1,400 ml. of fresh ethanol. The alcohol was removed by filtration and the two alcoholic extracts combined. The ethanol extracts were concentrated under partial vacuum and heating in a water bath to a volume of approximately 300 ml.

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 888, Purdue University, Lafayette, Indiana.

[2] The authors express their appreciation to Dr. George O. Kohler of the Cerophyl Laboratories and Mr. Joseph Chrisman of the American Dehydrators Association for some of the grass and legume samples.

This alcoholic concentrate was mixed with 300 gm. of a standard laboratory mouse ration and the alcohol allowed to evaporate in an oven at 170° F. The final weight of the plant material was adjusted to 350 gm. by the addition of the standard laboratory mouse ration; thus one gram of the mixture to be assayed represented 1.0 gm. of the original dried plant material which was extracted with alcohol.

Female mice of the Rockland Swiss strain were ovariectomized between 8 and 10 weeks of age. Eight days after castration the mice were allotted into assay groups and were then checked for complete-

TABLE 1. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY

(First Growth)

Stage of maturity	No. of mice	Mean body wt.	Mean uterine wt.	% Body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
		gm.	mg.		mg.	gm.	mcg./lb.
Vegetative	9	23.3	20.0±1.4*	0.086	3.2*	29.8	...
"	10	22.8	17.7±1.0	0.086	1.3	28.3	...
"	10	22.9	18.0±0.8	0.079	1.6	28.8	...
Early budding	8	21.1	33.4±2.7**	0.157**	16.6**	23.3	2.6
Budding	10	23.9	21.9±0.7**	0.093**	4.6**	28.3	<0.5
Pre-bloom	10	23.8	22.9±1.8*	0.097**	5.5*	28.8	<0.5
Tenth bloom	10	24.6	22.2±0.9**	0.091**	5.4**	26.4	<0.5
Fourth bloom	10	22.3	30.1±1.5**	0.138**	13.3**	23.0	2.2
Half bloom	9	23.0	32.0±2.0**	0.139**	14.7**	23.1	2.5
Full bloom	9	24.1	38.1±2.6**	0.152**	20.8**	26.7	4.3
Dough stage	8	22.3	34.1±1.5**	0.154**	16.8**	25.5	3.2
Seed heads mature	9	24.3	36.0±2.2**	0.149**	18.8**	24.9	3.9

* $P<0.05$.
** $P<0.01$.

ness of ovariectomy by taking vaginal smears for 6 days. Assays were begun on the 15th day following castration. Control mice which received only the standard laboratory ration were used during each assay. Two cages of mice were used for each substance tested. The mice were fed weighed amounts of feed twice daily for 10 days at the rate of 3 gm. per mouse per day. Twenty-four hours after the last feeding the mice were individually weighed, killed, and the uteri removed and trimmed of extraneous tissue. The uteri were split longitudinally, pressed between filter paper to remove free moisture, and weighed immediately.

A dose response curve was established by the oral administration of known amounts of diethylstilbestrol for a 10-day period.

Results

The estrogenic activity of alfalfa was compared at different stages of maturity in four crops during the Spring and Summer of 1954. As shown in table 1 there was considerable fluctuation in activity at different stages of maturity in the spring growth (first crop). There was a highly significant increase in estrogen in the early budding stage, followed by a decline until one fourth bloom. The estrogenic activity then remained at a relatively high level throughout bloom and including the mature seed head stage. The apparent association of estrogenic activity in alfalfa with the reproductive function of the plant during the Spring growth is in agreement with the conclusions of Legg *et al.* (1950) that estrogen is related to flowering in British pasture plants.

TABLE 2. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY
(Second Growth)

Stage of maturity	No. of mice	Mean body wt.	Mean uterine wt.	% Body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
		gm.	mg.		mg.	gm.	mcg./lb.
Vegetative	10	23.7	21.2±1.1**	0.090*	4.8**	27.3	<0.5
Early budding	10	25.0	24.6±1.1**	0.099**	7.8**	25.2	<0.5
Budding	9	23.7	23.0±1.0**	0.097**	5.7**	23.1	<0.5
Fourth bloom	9	22.8	21.5±1.1**	0.095**	4.2**	25.2	<0.5
Half bloom	9	24.1	22.4±1.2**	0.092**	5.1**	25.4	<0.5
Full bloom	10	24.0	20.5±0.7**	0.085**	4.2**	26.1	<0.5
Dough stage	9	23.6	38.5±1.9**	0.164**	22.2**	27.6	4.3

* $P<0.05$.
** $P<0.01$.

Walker and Janney (1930) reported that in non-pasture species high estrogen activity coincides with vegetative growth.

The pattern of estrogenic activity in terms of stage of plant growth and total quantity during the second, third, and fourth crops was considerably different than that of the original spring growth. In the second crop (table 2), although there were highly significant amounts of estrogen present, the estimated potency in terms of stilbestrol per pound of dry matter was much less than in the first crop and remained low until the plant reached the dough stage. The dough stage sample was sun-cured to a moisture content of 45 percent then artificially dried. It is therefore unknown whether there was an increase in estrogenic

TABLE 3. ESTROGENIC ACTIVITY OF ALFALFA AT VARIOUS STAGES OF MATURITY
(Third Growth)

Stage of maturity	No. of mice	Mean body wt.	Mean uterine wt.	% Body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
		gm.	mg.		mg.	gm.	mcg./lb.
Vegetative	10	23.2	20.8±0.8**	0.090**	3.9**	20.8	<0.5
Early budding	10	23.3	19.7±0.9	0.095**	1.9	20.9	...
Budding	10	23.7	18.6±0.5	0.079	0.7	23.5	...
Fourth bloom	10	25.1	20.4±1.3	0.080	2.4	26.5	...
Half bloom	10	25.2	21.1±1.8	0.084*	3.2	26.8	...
Full bloom	10	25.4	20.4±0.6**	0.081	2.8**	22.0	<0.5

* $P<0.05$.
** $P<0.01$.

activity between the full bloom and dough stage or whether the increased estrogenic activity was produced during the process of sun curing. Since this possibility was not recognized at the time of sampling it was not investigated.

The estrogen content of alfalfa at different stages of growth during the third and fourth cuttings is summarized in tables 3 and 4. In both crops the tendency for lower estrogenic activity in the budding stage and an increased activity with maturity occurred but the potency of the samples per unit weight was considerably less than in the spring growth.

An attempt was made to determine the distribution of estrogenic activity in the alfalfa plant. Samples of stems, leaves, and flowers were collected from the second growth of alfalfa in full bloom. As shown in

TABLE 4. ESTROGENIC ACTIVITY OF ALFALFA AT DIFFERENT STAGES OF MATURITY
(Fourth Growth)

Stage of maturity	No. of mice	Mean body wt.	Mean uterine wt.	% Body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
		gm.	mg.		mg.	gm.	mcg./lb.
Vegetative	10	24.0	20.2±0.8	0.085	2.3	26.9	...
Early budding	10	22.8	20.1±1.0	0.089	2.1	28.3	...
Budding	10	23.6	19.6±0.9	0.084	1.6	29.0	...
Pre-bloom	10	24.0	20.4±1.2	0.086	2.4	29.0	...
Tenth-bloom	10	24.6	23.2±0.9**	0.095**	5.2**	28.5	<0.5
Fourth-bloom	10	25.6	24.9±1.0**	0.098**	6.4**	27.0	<0.5

** $P<0.01$.

TABLE 5. DISTRIBUTION OF ESTROGENIC ACTIVITY IN THE ALFALFA PLANT

	Lot and treatment				
	1 Control	2 Flowers	3 Leaves	4 Stems	5 Entire Plant
No. of mice	10	10	10	9	10
Mean body wt., gm.	23.7	24.8	24.2	24.9	24.0
Mean uterine wt., mg.	16.3±0.7	19.8±1.0**	24.1±0.9**	19.0±0.6*	20.5±0.7**
Percent body wt.	0.069	0.080**	0.100**	0.077	0.085**
Av. feed consumption, gm.	27.3	26.0	25.9	25.9	26.1
Estimated potency (mcg. stilbestrol per lb. dry matter)	....	<0.5	<0.5	<0.5	<0.5

* P<0.05.
** P<0.01.

table 5, all the parts tested possessed activity. The leaves were more potent than the flowers while the stems exhibited the least activity. The same relationship was observed in subterranean clover (Robinson, 1949; Bennetts and Underwood, 1951) and in some British pasture species (Legg *et al.*, 1950).

The estrogenic activity of three samples of alfalfa hay is summarized in table 6. The 1952 samples were sun cured and data as to stage of growth at the time of harvest are not available. The 1953 sample was harvested in tenth bloom in the spring growth. It was sun cured to a moisture content of 45 percent and then dehydrated in a plant dryer

TABLE 6. ESTROGENIC ACTIVITY IN ALFALFA HAY

	Lot and treatment		
Cutting	1 Alfalfa hay first, 1953	2 Alfalfa hay second, 1952	3 Alfalfa hay third, 1952
No. of mice	9	9	9
Mean body wt., gm.	24.0	21.6	24.0
Mean uterine wt., mg.	79.1±4.0**	23.4±1.3**	36.1±3.1**
Percent body wt.	0.335**	0.019**	0.149**
Difference of uterine wt. from respective controls, mg.	62.3	6.6	20.8
Av. feed consumption, gm.	27.8	25.3	31.5
Estimated potency (mg. stilbestrol per lb. dry matter)	16.3	<0.5	5.6

** P<0.01.

to a moisture content of 6 to 9 percent. This sample had an estrogenic activity equivalent to 16.3 mcg. of stilbestrol per pound of feed.

As shown in table 7 the estrogenic activity of the grass species assayed was generally low.

The assays of a variety of legumes harvested in various stages of growth and at widely separated locations are summarized in table 8. Significant estrogenic activity was found in all samples but there was considerable variation between species and in the same species between samples. As previously pointed out differences in season, stage of growth and other environmental factors may affect hormonal activity.

TABLE 7. ESTROGENIC ACTIVITY IN GRASSES (GRAMINEAE)

Species and location	No. of mice	Mean body wt.	Mean uterine wt.	% body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
		gm.	mg.		mg.	gm.	mcg./lb.
Wheat, La. (Triticum aestivum)	9	22.4	22.2±1.6*	0.123	5.6*	38.8	<0.5
Rye grass, Kans.	8	19.9	15.0±1.2	0.076	−2.4	41.5	.....
Rye grass, Ind. (Lolium perenne)	9	23.6	20.3±0.7**	0.087	4.0**	29.0	<0.5
Oats, Can.	9	25.5	22.8±1.7**	0.089	7.5**	34.7	<0.5
Oats, La.	9	26.9	20.2±1.4	0.075	3.3	43.2	.....
Bromegrass, Ind. (Bromus inermis)	9	23.1	18.2±0.5	0.079	1.8	29.1	.....
Fescue, Ind. (Festuca arundinacea)	9	24.4	19.8±1.1	0.082	2.4	26.1	.....
Orchard grass, Ind. (Dactylis glomerata)	9	22.6	18.5±1.4	0.081	1.6	24.9	.....
Orchard grass, Wash.	10	26.3	18.8±1.1	0.072	1.3	24.3	.....

* $P<0.05$.
** $P<0.01$.

The estrogenic activity of several grains is shown in table 9. Koen and Smith (1945) reported the occurrence of genital stimulation in female swine fed moldy corn. A similar natural occurrence in which gilts consuming moldy corn exhibited genital stimulation was observed. Although estrogenic activity was detected in the corn sample the authors are of the opinion that the assay did not reflect the true estrogenic activity of the corn. The possibility that the estrogenic activity was increased during digestion in swine is discussed later.

In order to make comparisons of oral estrogenic activity, known quantities of diethylstilbestrol were added to the standard mouse ration.

TABLE 8. ESTROGENIC ACTIVITY IN LEGUMINOUS SPECIES (LEGUMINOSAE)

Species and location	Stage of maturity	No. of mice	Mean body wt.	Mean uterine wt.	Percent body wt.	Difference of uterine wt.	Av. feed consumption	Estimated potency
			gm.	mg.		mg.	gm.	mcg./lb.
Ladino clover, Kans.	Full bloom	9	22.2	19.9±1.3*	0.090	3.3*	34.1	<0.5
Ladino clover, Ind. (Trifolium repens)	Vegetative	10	21.8	26.2±1.8**	0.121**	9.8**	27.6	0.5
Ladino clover, Ind.	Vegetative	8	23.5	21.2±1.3*	0.090	3.9*	23.0	<0.5
Red clover, Kans.	Fourth bloom	8	17.5	22.4±1.9*	0.129**	5.0*	35.0	<0.5
Red clover, Ind. (Trifolium pratense)	Budding	10	21.2	46.6±2.4**	0.220**	30.2**	27.2	6.7
Red clover, Ind.	Full bloom	10	21.7	50.5±4.7**	0.235**	33.7**	22.0	9.8
Sweet clover, Ind. (Melilotus officinalis)	Budding	7	17.1	19.9±1.3	0.116**	2.5	14.8	<0.5
Birdsfoot trefoil, Ind. (Lotus corniculatus)	Vegetative	7	21.7	19.1±1.3*	0.089	2.8*	24.0	<0.5
Soybean plant, Ind.	Beans about half developed	10	26.2	18.7±0.9	0.071	0.7	28.8	.....
Alfalfa, Kans.	———	9	26.3	27.6±1.8**	0.105**	12.3**	36.1	0.7
Alfalfa, Tex.	Fourth bloom	10	23.6	25.6±1.7**	0.108**	7.6**	28.7	<0.5
Alfalfa, Ohio	Half bloom	10	23.8	44.4±3.6**	0.191**	26.4**	28.4	5.9
Alfalfa, Ind. (Medicago sativa)	Half bloom	9	23.0	32.0±2.0**	0.139**	14.7**	23.1	2.5

* $P<0.05$.
** $P<0.01$.

TABLE 9. ESTROGENIC ACTIVITY IN GRAINS

	Lot and Treatment					
	1 Control	2 Alfalfa seeds	3 Soybean oil meal	4 Cottonseed meal	5 Linseed meal	6 Moldy corn
No. of mice	30	10	10	10	10	10
Mean body wt., gm.	24.2	28.1	24.7	26.4	24.0	24.1
Mean uterine wt., mg.	17.8±0.9	21.1±0.5**	24.7±0.6**	26.0±0.7**	20.0±0.4**	23.4±1.3**
Percent body wt.	0.073	0.076	0.101**	0.099**	0.083	0.098**
Av. feed consumption, gm.	29.8	27.7	30.0	28.5	27.9	28.2
Estimated potency (mcg. stilbestrol per lb. dry matter)	....	<0.5	<0.5	0.5	<0.5	<0.5

** $P<0.01$.

TABLE 10. UTERINE WEIGHT RESPONSE TO ORALLY ADMINISTERED DIETHYLSTILBESTROL

Total dose of stilbestrol	No. of mice	Uterine wt. standard error
mcg. per animal		mg.
None	39	16.9±0.8
0.027	10	22.0±1.2
0.1	20	24.8±1.1
0.2	20	35.3±3.3
0.4	20	44.1±3.7
0.6	10	59.8±3.7
0.8	19	84.2±6.1
1.6	17	104.0±6.5

These data are summarized in table 10 and are presented in a linear regression line (Snedecor, 1946) in figure 1.

Discussion

Most of the earlier studies on the estrogenic activity in plant materials involve non-pasture species. Estrone and estriol have been isolated from palm kernel oil (Butenandt *et al.*, 1933) and female willow flowers (Skarzynski, 1933). More recent work with pasture species would tend to indicate that most, if not all, of the estrogenic activity in these species is contributed by one or more of the isoflavone pigments. Bradbury and White (1951) reported that the isoflavone, genistein, isolated from subterranean clover is responsible for the

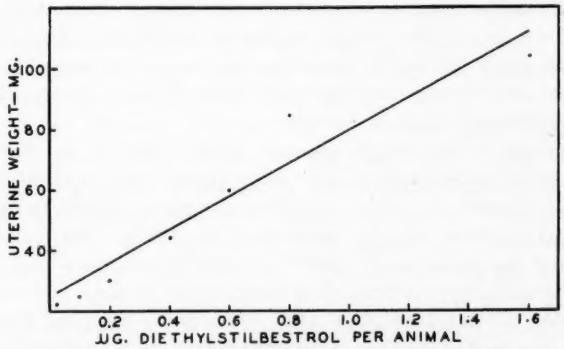


Figure 1. Uterine weight response to orally administered diethylstilbestrol.

estrogenic activity in that species. Genistein was also isolated from soybean oil meal (Cheng *et al.*, 1953) and red clover (Pope and Wright, 1954). The principal estrogen of red clover was, however, found to be another isoflavone, biochanin A (Pope *et al.*, 1953). No attempt has been made in this study to identify the chemical nature of the estrogenic substances in the plant materials since the primary interest was concerned with the total estrogenic activity present in the feeds.

Alexander and Watson (1951) found that the estrogenic activity of subterranean clover increased after repeated cuttings or grazing. In the current study a decline in activity was noted in alfalfa after the first and second cuttings. On the other hand, third-cutting alfalfa hay was more potent than second-cutting hay. The discrepancy between the results obtained with freshly cut alfalfa samples and alfalfa hay samples may be attributed to different stages of maturity at which the hays were harvested, different climatological and soil conditions, as well as some hitherto unknown biochemical changes in the plant after cutting. Shier and Rossiter (1949) reported that dry clover and hay possessed a very low activity. In this study alfalfa hays were found to have a relatively high activity, in fact, one alfalfa hay sample was found to be more potent than any of the alfalfa pasture samples. Whether this would indicate that the estrogen in alfalfa is some compound other than that in subterranean clover and that its potency actually increases with sun-curing, remains an open question.

Bennetts and Underwood (1951) and Legg *et al.*, (1950) observed considerable variation in the estrogenic activity of pasture plants during different seasons of the year. In the present research it was difficult to determine whether the variation in activity of alfalfa was due to seasonal changes or the number of previous cuttings of the forage. Furthermore, the activity may vary markedly during the same season with the plant in different stages of maturity.

Redemann (1950) found that the yellow pigment in corn (Zea Mays) pollen is quercitin. Since it was found in this investigation that quercitin acquired a notable increase in estrogenic activity following a slight change in its chemical structure, it is possible that a flavonoid compound was present in the moldy corn which could have been altered in the porcine digestive tract to a more potent estrogen and that this conversion did not take place when administered to mice. This may explain the marked estrogen stimulation noted in the gilts fed moldy corn.

In spite of the relatievly high estrogenic activity detected in some plant materials assayed, and the temptation to speculate on the practical implication it may have on domestic animals consuming these forages, it is felt that inferences from these data obtained with mice as experimental animals could be misleading. In the first place, it is well-known that different animal species differ markedly in their responsiveness to the same biological preparation. Furthermore, it was observed in a companion study with silage, that under certain conditions the estrogenic activity of the plant increases several fold when subjected to the process of ensiling (Pieterse and Andrews, 1955). Similar changes may very likely also occur in the digestive tract of animals, especially in ruminants. These animals might, therefore, be exposed to a more potent estrogen from a sample of fresh forage than uterine weight assays of mice would indicate.

Summary

The estrogenic activity of alfalfa was compared at different stages of maturity in four crops during the Spring and Summer of 1954. There was considerable fluctuation in activity at different stages of maturity in the spring growth (first crop). There was a highly significant increase in estrogen in the early budding stage, followed by a decline until one fourth bloom. The estrogenic activity then remained relatively high throughout bloom and during the seed head stage. The pattern of estrogenic activity in relation to stage of maturity during the second, third and fourth crops was considerably different than during the spring growth. In the second crop activity remained low until the dough state and in the third and fourth crops tended to increase after budding. In all three crops estrogenic activity was less than in the spring growth. Alfalfa leaves were more active than the flowers and the stems had the least activity.

Significant estrogenic activity was detected in ladino clover, red clover, birdsfoot trefoil, wheat, rye and oats. The samples of sweet clover, soybean plant, brome grass, fescue and orchard grass did not contain detectable estrogenic activity.

Fish solubles, fish meal, and dried distillers solubles were not estrogenic. Soybean oil meal and moldy corn contained detectable estrogens.

It appears that there is considerable variation in estrogenic activity between and within plant species and that differences in season, stage of growth and other environmental factors may affect hormonal activity.

Literature Cited

Alexander, G. and R. H. Watson. 1951. The assay of oestrogenic activity of Trifolium Subterraneum L. by increase in uterine weight in the spayed guinea pig. II Assays. Aust. Jour. Agr. Res. 2:480.

Andrews, F. N., W. M. Beeson and C. Harper. 1949. The effect of stilbestrol and testosterone on the growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE 8:578.

Bennetts, H. W. and E. J. Underwood. 1951. The oestrogenic effects of subterranean clover (Trifolium Subterraneum). Uterine maintenance in the ovariectomized ewe on clover grazing. Aust. Jour. Exp. Biol. Med. Sci. 29:249.

Bennetts, H. W., C. J. Underwood and F. L. Shier. 1946. A specific breeding problem of sheep on subterranean clover pastures in Western Australia. Aust. Vet. Jour. 22:2.

Bradbury, R. B. and D. E. White. 1951. The chemistry of subterranean clover. Part I. Isolation of formononetin and Genistein. Jour. Chem. Soc. Proc. p. 3447.

Burroughs, W., C. C. Culbertson, J. Kastelic, E. Cheng and W. H. Hale. 1954. The effect of trace amounts of diethylstilbestrol in rations of fattening steers. Science 120:66.

Butenandt, A. and H. Jacobi. 1933. Uber die Darstellung eines krystallisierten pflanzlichen Tokokinins (Thelykinins) und seine Identifisierung mit dem alpha Follikelhormon. Untersuchungen uber das weibliche Sexualhormon. Z. Physiol. Chem. 218:104.

Cheng, E., C. D. Story, L. Yoder, W. H. Hale and W. Burroughs. 1953. Estrogenic activity of isoflavone derivitives extracted and prepared from soybean oil meal. Science 118:164.

Geissman, T. A. and E. Hinreiner. 1952. Theories of the biogenesis of flavonoid compounds. Botan. Rev. 18:77.

Gilman, H. 1947. Organic chemistry; and advanced treatise. Vol. II. 2nd. ed. John Wiley and Sons, Inc., New York.

Koen, J. S. and H. C. Smith. 1945. An unusual case of genital involvement in swine associated with eating moldy corn. Vet. Med. 40:131.

Legg, S. P., D. H. Curnow and S. A. Simpson. 1950. The seasonal and species distribution of oestrogen in British pasture plants. Biochem. Jour. 46:19.

Lorenz, F. W. 1945. The influence of diethylstilbestrol on fat deposition and meat quality in chickens. Poultry Sci. 24:128.

Pieterse, P. J. S. and F. N. Andrews. 1955. The estrogenic activity of legume, grass and corn silage. J. Dairy Sci. (in press).

Pope, G. S., R. V. Elcoate, S. H. Simpson and D. G. Andrews. 1953. Isolation of an oestrogenic isoflavone. (Biochanin A) from red clover. Chem. and Ind. Proc. 1092.

Pope, G. S. and H. G. Wright. 1954. Oestrogenic isoflavones in red clover and subterranean clover. Chem. and Ind. Proc. 1019.

Redemann, C. T. 1950. The occurrence of quercetin in the pollen of Zea Mays. Arch. Biochem. 25:277.

Robinson, T. J. 1949. Oestrogenic potency of subterranean clover (T. Subter raneum L. var. Dwalganup): The preparation and assay of extracts. Aust. Jour. Exp. Biol. Med. Sci. 27:297.

Shier, F. L. and R. C. Rossiter. 1949. Clover disease: Practical findings and recommendations for control. Jour. Dept. Agr. W. Aust. 26:111.

Skarzynski, B. 1933. An oestrogenic substance from plant material. Nature 131:766.

Snedecor, G. W. 1946. Statistical Methods. Iowa State College Press, Ames, Iowa.

Walker, B. S. and J. C. Janney. 1930. Estrogenic substances. II. An analysis of plant sources. Endocrinology 14:389.

FURTHER STUDIES ON THE ANABOLIC EFFECT OF STILBESTROL IN CATTLE AS INDICATED BY CARCASS COMPOSITION

M. T. Clegg and F. D. Carroll [1]

University of California

THE implantation of stilbestrol in cattle and sheep causes an increase in rate of gain and efficiency of food utilization (Dinusson *et al.*, 1950; Andrews *et al.*, 1949 and others). Whitehair *et al.* (1953) and Clegg and Cole (1954) reported that stilbestrol caused a significant increase in nitrogen retention in lambs and in steers. Numerous reports on lambs have indicated that stilbestrol treatment results in a reduction of fat deposition (Andrews *et al.*, 1949; O'Mary *et al.*, 1952 and others). O'Mary *et al.* (1952) reported that there was a greater water content in treated lambs and suggested that this might account for some of the increased gain. Clegg and Cole (1954) on the basis of their studies postulate that stilbestrol stimulates an increased secretory activity of the anterior pituitary which in turn brings about an increase in the release of some protein anabolic hormone from the adrenal possessing androgenic activity. This adrenal material was the substance responsible for the growth effect. Papanicolaou and Falk (1938) reported that the temporal muscle of the guinea pig was larger following the injection of testosterone propionate. That androgens are effective in cattle has been shown by Burris *et al.* (1953) who demonstrated that the weekly injection of testosterone propionate into steers and heifers will result in a higher rate of average daily gain and an increase in efficiency of food utilization.

This study was undertaken to determine if stilbestrol, likewise, caused changes in protein and fat formation as well as muscular development in beef animals.

Methods

During the period 1954 and 1955, three separate trials were conducted. In trial 1, 16 two-year-old Hereford steers were randomly divided into two groups of 8 animals. Group I was untreated and served as a control group. Group 2 received 60 mg. (five 12 mg. pellets) of

[1] Department of Animal Husbandry, Davis.

stilbestrol by subcutaneous implantation into the ear. The concentrate portion of the ration consisted of 65 percent ground barley, 20 percent molasses dried beet pulp and 15 percent ground oats. The roughage consisted of one-half alfalfa and one-half oat hay. The entire experiment was replicated in the second trial. In trial 3, 28 Hereford and Hereford-Angus crossbred heifers of approximately one year of age were divided into four groups as follows: Group I, Spayed untreated; Group II, Spayed treated with 60 mg. (four 15 mg. pellets) by subcutaneous implantation in the ear; Group III, Intact untreated; and Group IV, Intact treated with 60 mg. (four mg. pellets) by subcutaneous implantation in the ear.

The spayed animals were operated upon 19 days prior to the beginning of the experiment. The removal of the ovaries was accomplished by way of a ventral incision. All heifers in this experiment received a ration consisting of 65 percent ground barley, 20 percent molasses dried beet pulp, 10 percent ground oats, and 5 percent cottonseed meal (41 percent protein). The roughage contained two-thirds alfalfa hay and one-third oat hay.

The ratio of concentrate to roughage for each trial was as follows: Trial No. 1, 55:45; Trial No. 2, 60:40; and Trial No. 3, 65:35.

All the animals of all trials came from the University of California's range herd and were above average in uniformity of breeding, age, and quality.

At the end of the experimental period for all trials, two animals from each group were selected on the basis of comparable finish and slaughtered at a local packing house. Dressing percentage and U.S.D.A. carcass grades were obtained at this time. The average experimental period for trial 1 was 97 days, for trial 2, 185 days and for trial 3, 217 days.

The fat content of the carcasses of the steers was estimated from specific gravity measurements of a seven rib section (6th, 7th, 8th, 9th, 10th, 11th and 12th ribs). In addition, the density of the 12th rib section was determined separately. Fat content was calculated using the values 1.155 and 0.894 as the specific gravities of the fat free body and beef fat, respectively (Lofgreen and Garrett, 1954). The area of the eye muscle, *longissimus dorsi*, was determined by tracing the outline at the 12th rib section and subsequently measuring the area by a planimeter. The moisture content and percent ether extract were determined for the separated eye muscle of the 12th rib cut. In the case of the steers for both trials, an analysis of the percentage wholesale

cutout values was made by a local meat jobber. In trials 1 and 2, blood plasma and serum were collected from all animals once prior to treatment and again 80 days and 40 days, respectively, after the start of the trial. Analysis was made for serum protein bound iodine by the method of Brown *et al.* (1953) for blood glucose and non-protein nitrogen by the methods of Folin and Wu as described in Hawk *et al.* (1951). In addition serum potassium and sodium were determined by flame photometry. At slaughter, the seminal vesicles were dissected out, weighed and fixed in Bouin's solution. Histological observations were made on the haemotoxylin-eosin stained sections.

Results

Feed-lot Performance and Slaughter Data

Table 1 summarizes the results of the treatments on gains, feed consumption, feed utilization, dressing percentage and slaughter grades. In trial 1, the average daily gains of the treated animals were significantly greater ($P < .01$) than the untreated controls. In trial 2, however, a statistically significant difference was not obtained. The fact that the treated animals maintained a higher average daily gain throughout the experiment, with the exception of one period between the 141st and the 167th day, would suggest that the treatment was effective in increasing the growth response. The period of poor gains occurred during a severe infection of foot-rot. During this time, three of the treated steers actually lost weight. Thus it is doubtful that the average daily gain reflects a true picture of the growth response after this time. Since the treated steers consistently gained more rapidly than the controls, it seems likely that had this infection not occurred they would have continued to respond with greater gains. Figure 1 is a comparison between the percent increase in gain during 28 to 56-day intervals of treated steers and heifers over controls. In all trials, the maximum increase in gain occured during the second and third 28-day periods or between the 60th and 80th day following treatment. It is interesting that the treated animals continued to show increased gains, as in the case of the heifers, for as long as 200 days following treatment.

There was little difference in carcass grades between treated and control steers in trial 2. In trial 1, the treated steers graded somewhat lower. In the case of the heifers, the reduction in grade of the treated animals was even more apparent. In trials 1 and 2, treatment had no

TABLE 1. A SUMMARY OF DATA ON GAINS, FEED UTILIZATION AND SLAUGHTER DATA OF ALL TRIALS. ALL TREATED ANIMALS RECEIVED 60 MG. OF STILBESTROL BY IMPLANTATION IN THE EAR

	Trial No. 1 Steers		Trial No. 2 Steers		Trial No. 3 Heifers			
	Control	Treated	Control	Treated	Spayed control	Spayed treated	Intact control	Intact treated
Av. initial wt., lb.	930	938	832	842	404	424	404	420
Av. final wt., lb.	1171	1267	1255	1297	792	899	809	889
Av. daily gain, lb.	2.48	3.39**	2.29	2.46	1.80	2.15**	1.87	2.18**
Av. daily feed consumed								
Concentrates, lb.	15.5	15.4	15.2	15.2	9.9	10.9	10.0	11.1
Roughage, lb.	13.2	15.2	10.4	10.4	5.6	6.8	6.4	7.3
Total, lb.	28.7	30.6	25.6	25.6	15.5	17.7	16.4	18.4
Feed per 100 lb. gain								
Concentrate, lb.	625	454	664	615	549	501	552	520
Roughage, lb.	532	448	454	421	312	313	354	343
Total, lb.	1157	902	1118	1036	857	814	906	863
Slaughter data								
Yield, percent	58.9	59.0	60.9	61.1	61.2	60.2*	61.2	59.5*
Prime (No head)			0	1	3	1	0	0
Choice (No head)	3	1	8	7	4	3	7	3
Good (No head)	5	7			0	3	0	4

* Significant at 5 percent level.
** Significant at 1 percent level.

effect upon yield. In trial 3, however, there was a significant reduction in the dressing percentage of the treated heifers.

It is possible that the greater age and longer feeding period may have

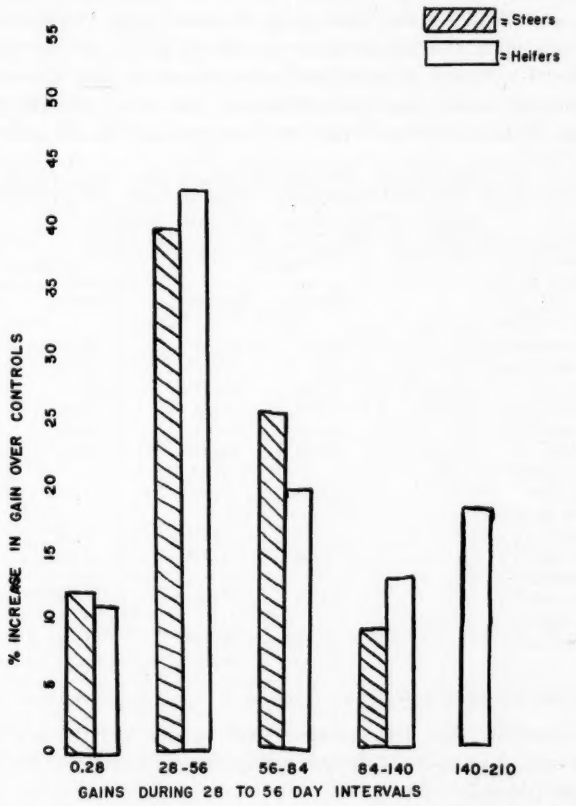


Figure 1. The percentage increase in gain of animals treated by implantation of 60 mg. of stilbestrol over untreated controls during 28 to 56 day intervals.

contributed to the more desirable finish observed in the treated carcasses of trial 2.

Spaying had no effect on growth response, dressing percentage or carcass grade.

Carcass Cutout Values

The percentage cutout values of the front and rear quarters were not significantly different from the controls; nor was there a difference in the percentage weight of the trimmed loin (top sirloin, strip loin, cubes and filet). On the other hand, in trial 1, the untrimmed drop loin made up a significantly lower percentage of the treated carcasses because of a significant reduction in the amount of suet. The shoulder cut (counter chuck) was also significantly heavier as was the kidney. In trial 2, these differences were not as apparent, but the same trend

TABLE 2. A COMPARISON OF THE PERCENTAGE WHOLESALE CARCASS CUTS OF STEERS TREATED WITH 60 MG. OF STILBESTROL WITH UNTREATED CONTROL STEERS

Cuts	Trial No. 1		Trial No. 2	
	Control	Treated	Control	Treated
Front quarters	51.79	52.38	52.19	51.91
Counter chuck	16.16	16.77*	15.86	16.23
Arm	11.35	11.32	11.12	11.18
Brisket	5.51	5.33	6.03	5.68
Rear quarter	48.21	47.62	47.81	48.09
Drop loin	24.03	23.12*	24.24	24.54
Top sirloin, Strip loin, Cubes & filet	12.78	12.69	11.94	12.16
Kidney	.30	.33*	.28	.27
Loin suet	4.00	3.02*	4.03	4.27
Gooseneck, Top round, Knuckle	17.24	17.86	16.97	17.00
Round suet	1.48	1.24*	1.59	1.34*
Bones	10.12	9.82	9.12	9.31

* Significant at 5 percent level.

was suggested. Thus the shoulders were heavier and the brisket and round suet make up a smaller percentage of the carcasses of the treated animals (table 2).

Physical Analysis of the 12th Rib Cut

Table 3 gives the analysis of the 12th rib cut. There was less separable fat and more lean in the treated than in the control animals. These differences, however, were only significant in the case of the heifers. In the treated steers, there was no difference in percent bone or percent moisture. Moisture content, however, was increased in the treated heifers. The percent ether extract present in the rib eye muscle was

less in the treated group, but again the significance of this difference could only be demonstrated in the case of the heifers. The eye muscle area of the treated animals was in every trial significantly greater ($P < .05$). The average percent fat for trial 1, as calculated from the specific gravity of the seven rib cut (6th, 7th, 8th, 9th, 10th, 11th and 12th) was 35.7 percent for the control steers. This value for the treated steers was 33.1 percent which was significantly less than the controls ($P < .05$). In trial 2, the calculated fat percent was 42.6 percent for control steers and 41.2 percent for treated steers. This difference was not significant. In trial 3 the calculated values were as follows: spayed untreated heifers, 42.4 percent; spayed treated heifers, 38.7 percent;

TABLE 3. AN ANALYSIS OF THE 12TH RIB CUT OF UNTREATED AND STILBESTROL IMPLANTED ANIMALS [a]

Trial No.	Fat [b]	Separable fat	Separable lean	Bone	Moisture	Ether ext.	Eye muscle area
	%	%	%	%	%	%	sq. in.
1. Steers							
Control	41.5	38.3	45.8	15.7	74.8	2.64	9.8
Treated	39.8	35.2	49.4*	15.3	74.2	1.99	10.9*
2. Steers							
Control	50.6	46.9	40.6	11.9	74.1	4.78	10.3
Treated	47.5	43.6	43.7*	12.2	73.7	4.29	11.3**
3. Heifers							
Spayed control	50.5		38.9	10.7	73.4	5.81	7.95
Spayed treated	46.1*		42.4*	11.5	74.6*	4.30**	9.03*
Intact control	49.6		40.2	10.2	73.0	6.05	8.45
Intact treated	47.0*		41.3*	11.7	74.2*	4.33**	8.74*

* Significant at 5 percent level.
** Significant at 1 percent level.
[a] See table 4 for an analysis of variance of spayed, open, stilbestrol treated and untreated heifers.
[b] Calculated from density of the 12th rib.

intact untreated heifers, 44.1 percent; and intact treated heifers, 40.8 percent.

In this case, the treatment resulted in a significant ($P < .01$) reduction in fat content. Spaying, however, had no effect on fat content or on any of the other carcass constituents studied, nor was there any interaction between spaying and treatment. The analysis of variance of the data is shown in table 4.

Analysis of Blood Constituents

There was no difference in the average value of the serum protein-bound iodine between the treated and control groups; nor was there a difference in the average values between different times of bleeding

TABLE 4. ANALYSIS OF VARIANCE OF 12TH RIB CONSTITUENTS BETWEEN SPAYED STILBESTROL IMPLANTED, SPAYED UNTREATED, INTACT IMPLANTED, AND INTACT UNTREATED HEIFERS

	Degrees of freedom	Mean square					
		Moisture	Lean	Fat	Bone	Ether extract	Eye muscle area
Source of variation							
Hormone	1	10.12	35.1	80.24	8.16	17.73	2.85
Spayed	1	1.08	0	.28	.13	.12	.03
Interaction	1	0	9.57	.03	.82	.07	.92
Individuals	23	1.62	7.87	12.43	2.61	1.52	.50
F value *							
Hormone		6.29	4.46	6.46	3.13	11.67	5.69
Spayed		.67	0	.04	.05	.08	.06

* F value for significance at 5 percent level 4.28; at 1 percent level 7.88.

regardless of treatment. The average values of serum protein-bound iodine for the untreated steers were: before treatment, 5.85 mcg. per 100 ml.; 80 days after treatment, 5.21 mcg. per 100 ml.; and at slaughter, 5.86 mcg. per 100 ml. In the treated animals, the average values were: before treatment, 6.17 mcg. per 100 ml.; 80 days after treatment, 5.70 mcg. per 100 ml.; and at slaughter, 6.03 mcg. per 100 ml. In addition, treatment had no effect on blood levels of glucose, non-protein nitrogen, potassium and sodium (table 5).

Histology of the Seminal Vesicles

The seminal vesicles of the treated animals were greatly hypertrophied. The average weight of the paired glands was 34.0 gm. as contrasted to an average weight of 8.5 gm. for the untreated control

TABLE 5. A COMPARISON OF SOME OF THE BLOOD CONSTITUENTS BETWEEN STILBESTROL TREATED STEERS AND CONTROLS. ANALYSIS REFERS TO BLOOD SAMPLES OBTAINED AFTER TREATMENT WITH 60 MG. OF STILBESTROL BY SUBCUTANEOUS IMPLANTATION

	Blood glucose	NPN	K *meq.* 1	Na *meq.* 1	Protein-bound iodine
	mg./100 ml.	mg./100 ml.			mcg./100 ml.
Trial No. 1					
Control	56.1	29.2	6.2	133	5.21
Treated	59.7	28.8	5.6	143	5.70
Trial No. 2					
Control	67.6	28.7	6.5	181	
Treated	66.8	27.6	6.5	180	

steers. Histological studies show the epithelial cells of the seminal vesicles of the treated animals to be increased in height with basilar nuclei containing fine mitochondrial filaments and prominent nucleoli. Secretory granules can be noted in the apical portion of the cells. Those of the untreated animals are low cuboidal with centrally located nuclei containing clumped mitochondria. The fibrous tissue was, likewise, hypertrophied in the treated glands. These effects suggest that treatment causes a stimulation of the fibrous tissue as well as a stimulation of the secretory activity of the epithelial cells lining the vesicles. There was no apparent effect on smooth muscle tissue.

Discussion

The results of physical and chemical analysis of the 12th rib cut indicate differences in carcass composition as a result of stilbestrol treatment. Thus the percentage of fat was less and, the percentage of protein greater. Clegg and Cole (1954) have previously reported an increased nitrogen retention in steers treated with stilbestrol. These results, therefore, further substantiate an increased protein anabolic activity. There was a trend toward heavier shoulders, lighter briskets, and reduced suet in the treated steers. Although in the case of older animals maintained over a longer feeding period as in trial 2, these effects were not as apparent. The nature of these alterations might suggest a carcass tending toward that of a non-castrate animal. That there was no difference in bone or percentage moisture between treated and untreated steers indicates that the increased gains following treatment were not due to an effect upon bone development nor could the additional weight be accounted for on the basis of increased water content of the tissues. In younger animals, as in the case of the heifers of trial 3, moisture content was significantly increased by treatment and there was a suggestion of a greater percentage of bone. These differences occurred in spite of a feeding period lasting over 200 days. The results seem to suggest that treatment of young growing animals caused a more prolonged and perhaps irreversible effect on the carcass as compared to treatment of older steers. Since the serum-bound iodine was not changed, it is doubtful that the thyroid was affected to any great extent by stilbestrol treatment.

The greater kidney size of the steers of trial 1, the increased weight of the seminal vesicles and the greater cross-sectional area of the muscle of all trials suggest an androgenic effect. It is true that, in castrate

rats, estrogens cause a fibrotrophic effect on seminal vesicles, but most investigators agree that there is a lack of effect of estrogens on the glandular epithelium (Emmens and Parkes, 1947). Cavazos and Melampy (1954) among others, have presented evidence that the epithelial cell height of the seminal vesicles is correlated with the level of male hormone present. In our studies, the stimulation of the epithelial cells as well as the increase in fibrous tissue would indicate a combination of both male and female hormonal action.

We have previously reported an increased incidence of vaginal prolapse in heifers treated with stilbestrol (Clegg and Cole, 1954). These effects were not observed in the treated heifers of the present trial. There was, however, an appearance of looseness and edema around the vulva of the open treated animals. These effects were not apparent if the animals were spayed before treatment. Another observation of interest was the extensive mammary development which occurred in the spayed treated group. This development was noticeably greater than that which occurred in the open treated animals.

Summary

During 1954 and 1955, three trials were carried out to determine the effect of stilbestrol on fat and protein deposition in the carcass. In trial 1, 16 two-year-old Hereford steers were divided into two equal groups. Group 1 served as a control group, group 2 was implanted in the ear with five 12 mg. pellets of stilbestrol. The animals were maintained on a fattening ration for 104 days, at which time they were slaughtered. Trial 2 was a replication of trial 1 except the feeding period extended for 185 days. In trial 3, 28 yearling heifers were divided into four groups as follows: Group I, spayed untreated; group II, spayed implanted with 60 mg. of stilbestrol in the year; group III, intact untreated; group IV, intact implanted with 60 mg. of stilbestrol in the ear. These animals were maintained on a fattening ration for 217 days before being slaughtered. Carcass cutout values, analysis of the percentage of separable fat, lean and bone of the 12th rib cut, analysis of blood constituents and histological studies of the seminal vesicles were made on appropriate animals. The data indicate that stilbestrol treatment resulted in a decreased fat deposition and an increased protein anabolism.

Treatment did not affect the percentage of bone nor the percentage of moisture in the steers, but caused a significant increase in moisture percentage in the heifers. Levels of plasma glucose and non-protein

nitrogen, serum protein-bound iodine, potassium and sodium were unaffected by stilbestrol. There was a significant increase in the cross-sectional area of the eye muscle in all trials and an enlargement of the kidney of treated steers in trial 1. The average daily gain was increased as a result of stilbestrol treatment. Carcass grades were in some cases lowered and, in heifers but not in steers, dressing percentage was also reduced as a result of treatment.

Spaying had no effect on carcass grades, dressing percentage, average daily gains, or carcass constituents.

Histological studies of the seminal vesicles indicate a stimulated epithelium as well as an increased development of fibrous tissue.

Literature Cited

Andrews, F. N., W. M. Beeson and Claude Harper. 1949. The effects of stilbestrol and testosterone on growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE 8:578.

Brown, H. A., A. M. Reingold and M. Samson. 1953. The determination of protein-bound iodine by dry ashing. Jour. Clin. Endocr. 13:444.

Burris, M. J., R. Bogart and A. W. Oliver. 1953. Alteration of daily gain, feed efficiency, and carcass characteristics in beef cattle with male hormones. JOURNAL OF ANIMAL SCIENCE 12:740.

Cavazos, L. F. and R. M. Melampy. 1954. Cytological effects of testosterone propionate on epithelium of rat seminal vesicles. Endocr. 54:640.

Clegg, M. T. and H. H. Cole. 1954. The action of stilbestrol on the growth response in ruminants. JOURNAL OF ANIMAL SCIENCE 13:108.

Dinusson, W. E., F. N. Andrews and W. M. Beeson. 1950. The effects of stilbestrol and testosterone, thyroid alteration, and spaying on growth and fattening of beef heifers. JOURNAL OF ANIMAL SCIENCE 9:321.

Emmens, C. W. and A. S. Parkes. 1947. Effect of exogenous estrogens on the male mammal. Vitamins and Hormones 5:233.

Hawk, P. B., B. L. Oser and W. H. Summerson. 1951. Practical physiological chemistry. The Blakiston Co., Philadelphia, Pa. Twelfth edition, pp. 493 and 520.

Lofgreen, G. P. and W. N. Garret. 1954. Creatinine excretion and specific gravity as related to the composition of the 9, 10, 11th rib cut of Hereford steers. JOURNAL OF ANIMAL SCIENCE 13:496.

O'Mary, C. C., A. L. Pope, G. D. Wilson, R. W. Bray and L. E. Casida. 1952. The effects of diethylstilbestrol, testosterone, and progesterone on growth and fattening and certain carcass characteristics of western lambs. JOURNAL OF ANIMAL SCIENCE 11:656.

Papanicolaou, G. N. and E. A. Falk. 1938. General muscle hypertrophy induced by androgenic hormone. Science 87:238.

Whitehair, C. K., W. D. Gallup and M. C. Bell. 1953. Effect of stilbestrol on ration digestibility and on Ca, P, and N retention in lambs. JOURNAL OF ANIMAL SCIENCE 12:331.

EFFECTS OF LOW LEVEL IMPLANTATION OF STILBESTROL IN STEERS ON PASTURE [1]

C. C. O'Mary and A. E. Cullison

University of Georgia

INCREASES in daily gain resulting from stilbestrol implanted at various dosage levels have been reported with steers (Andrews *et al.*, 1953), heifers (Dinusson *et al.*, 1950) and lambs (Andrews *et al.*, 1949; Jordan, 1950; Pope *et al.*, 1950) in drylot feeding experiments. Burroughs *et al.* (1954) have also reported increased gains from the oral administration of stilbestrol to steers in drylot.

However, very little work has been reported on the effects of stilbestrol in animals on pasture. Perry *et al.* (1951) and Clegg *et al.* (1955) showed that the implantation of stilbestrol significantly increased the gain of grazing lambs. Clegg and Cole (1954) indicated that steers on pasture subcutaneously implanted with 120 mg. stilbestrol showed no significant increase in gain over control steers and developed the undesirable characteristics sometimes associated with the implantation of this synthetic estrogen.

The oral administration of stilbestrol to steers on pasture presents a problem in dosage administration and control. If the desired effect could be had from the subcutaneous implantation of stilbestrol in steers on pasture, the dosage could be controlled more effectively and much less of the stilbestrol would be required.

The purpose of the present study was to determine if the implantation of stilbestrol at a low level would significantly increase the growth rate of steers on pasture. In work by O'Mary *et al.* (1953) it appeared that for certain drylot rations the implantation of approximately 36 mg. per steer proved to be an effective level. Since the 36 mg. level was effective in drylot feeding tests and some pasture plants contain estrogenic substances (Legg *et al.*, 1950), the 24 mg. level was decided upon for the study in question.

Experimental

Two experiments were conducted almost concurrently with two different groups of steers. The first experiment involved 15 yearling and

[1] Contribution from the Department of Animal Husbandry, Athens, Georgia. Journal Paper No. 19 of the College Experiment Station. The stilbestrol used in this experiment was furnished by W. S. Davidson of Wick and Fry, Inc.

two-year-old Hereford steers in thin condition. These steers were weighed, arrayed in order of weight and the odd numbered animals implanted in the ear with 24 mg. of stilbestrol per steer. The steers were placed on a pasture of mixed grasses and legumes (mostly oats and alfalfa) on March 24, 1955 and were taken off test 69 days later, weighed and sold at the local market.

In the second experiment 21 yearling Angus and Hereford steers, in considerably better flesh than the above animals, were weighed, assigned to treatment in the same manner as in the first experiment except that Hereford and Angus were arrayed in order according to breed. These steers were placed on a good oats and crimson clover pasture on March 30, 1955, and weighed off test 68 days later. Adequate pasture was available throughout the test periods of both experiments and no supplemental feed was given.

TABLE 1. EFFECTS OF LOW LEVEL IMPLANTATION OF STILBESTROL ON GAINS OF STEERS ON PASTURE

Item	Experiment I (69 days)		Experiment II (68 days)	
	Control	Treated	Control	Treated
No. of animals	7	8	10	11
Av. initial weight, lb.	650	660	592	612
Av. final weight, lb.	811	869	677	736
Av. gain per steer, lb.	161	209	85	124
Av. daily gain, lb.	2.33	3.02*	1.25	1.83**

* Significant at the 5 percent level.
** Significant at the 1 percent level.

Results and Discussion

The implantation of 24 mg. of stilbestrol per steer resulted in significant and highly significant increases in daily gains in steers in experiments I and II respectively. The results are shown in table 1.

In experiment I the treated steers gained 3.02 lb. per head daily compared to 2.33 for the controls. The difference of .69 lb. per steer daily represents a significant increase as a result of the synthetic estrogen treatment. At the end of the experiment the steers were hauled a distance of seven miles to market. Under these conditions there was no measurable difference in shrink between the treated and control groups. There was no difference in sale price per cwt. at the local auction market between the two groups of steers.

In Experiment II the daily rate of gain for the treated steers was 1.83 lb. while that of the control was 1.25 lb. The difference of .58 lb. per steer daily in favor of the treated group was highly significant. The average initial weights of the control and treated group differed by 20 lb. However, rate of gain and initial weight were not significantly correlated ($r=-.21$). Therefore, no adjustment for initial weight was made.

No ill effects of treatment on the steers were noted at any time during the tests.

The pastures and steers of the two experiments were considerably different yet the results were essentially the same in both experiments in so far as treatment effects were concerned. A dosage level of 24 mg. of stilbestrol seems to be generally effective in stimulating steers on pasture to gain at a more rapid rate. These experimental results were obtained over a time interval of 68 and 69 days respectively. The effects of a low level of stilbestrol over a longer period of time are yet to be determined. Clegg and Cole (1954) failed to obtain a significant increase in gain with a higher level of synthetic estrogen over a longer period.

No carcass information was obtainable under the conditions of this test nor were any determinations made for the presence of estrogenic activity in the tissues.

Summary

Two experiments involving 36 steers were conducted to determine the effects of stilbestrol implanted in steers on pasture. In experiment I Hereford steers implanted with 24 mg. of stilbestrol per head had a significant increase in gain of .69 lb. per steer daily over the controls. In experiment II Angus and Hereford steers treated the same as in experiment I had an average increase in daily gain of .58 lb. over the controls. This difference was highly significant.

Literature Cited

Andrews, F. N., W. M. Beeson and C. Harper. 1949. The effects of stilbestrol and testosterone on the growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE 8:518.

Andrews, F. N., W. M. Beeson and F. D. Johnson. 1950. The effects of hormones on the growth and fattening of yearling steers. JOURNAL OF ANIMAL SCIENCE 9:677.

Burroughs, Wise, C. C. Culbertson, Joseph Kastelic, Edmund W. Cheng and William H. Hale. 1954. Oral administration of diethylstilbestrol for growth and fattening of beef cattle. JOURNAL OF ANIMAL SCIENCE 13:978.

Clegg, M. T., Reuben Albaugh, Joseph Lucas and W. C. Wier. 1955. A comparison of the effect of stilbestrol on the growth response of lambs of different age and sex. JOURNAL OF ANIMAL SCIENCE 14:178.

Clegg, M. T. and H. H. Cole. 1954. The action of stilbestrol on the growth response in ruminants. JOURNAL OF ANIMAL SCIENCE 13:108.

Dinusson, W. E., F. N. Andrews and W. M. Beeson. 1950. The effects of stilbestrol, testosterone, thyroid alteration and spaying on the growth and fattening of beef heifers. JOURNAL OF ANIMAL SCIENCE 9:321.

Jordan, R. M. 1950. The effect of stilbestrol on fattening lambs. JOURNAL OF ANIMAL SCIENCE 9:383.

Legg, S. P., D. H. Curnow and S. A. Simpson. 1950. The seasonal and species distribution of oestrogen in British pasture plants. Biochem. Jour. 46:XIX.

O'Mary, C. C., E. P. Warren, T. J. Davis and H. H. Pierce. 1953. The effects of stilbestrol on the performance of fattening steers fed blackstrap molasses. JOURNAL OF ANIMAL SCIENCE 12:952.

Perry, T. W., F. N. Andrews and W. M. Beeson. 1951. The effects of stilbestrol on suckling lambs. JOURNAL OF ANIMAL SCIENCE 10:602.

Pope, A. L., C. C. O'Mary, W. E. Batterman, R. W. Bray and L. E. Casida. 1950. The effect of certain steroid hormones on the growth, fattening and carcass quality of heavy lambs. JOURNAL OF ANIMAL SCIENCE 9:680.

EFFECTS OF LOW LEVEL IMPLANTATIONS OF STILBESTROL IN STEERS FATTENED ON DRY LOT RATIONS[1, 2]

C. C. O'Mary, E. P. Warren, T. J. Davis and H. H. Pierce, Jr.[3]
University of Georgia

THE dosage level appears to be an important factor in obtaining the desired physiological effects when estrogens are administered to various species of animals. Kochakian (1947) showed that in the implantation of estrogens low levels increased the body weight of mice while high levels tended to depress growth. In experiments with pigs Braude (1950) fed three different levels of iodinated casein and stilbestrol. His results indicated that the high level was too high and depressed growth at the beginning of the test, the medium level gave a good response and that the low level appeared to be too low near the end of the experiment. Clegg *et al.* (1951) reported that 60 mg. of stilbestrol increased body weight of steers and heifers but that the carcasses of the treated animals were poorer in all cases and that some heifers developed vaginal prolapse. Dinusson *et al.* (1950) obtained increased gains in heifers by use of 42 mg. of stilbestrol and obtained no significant differences in carcass grades or dressing percentages. They noted a "nymphomaniac stance," that is, elevated tail heads as a result of treatment.

Since gradations of responsiveness to estrogen appear to exist with respect to mice and pigs with the lower dosage seeming to give better results, experiments were designed to test the effectiveness of a lower dosage level of stilbestrol in obtaining increased weight gains in steers and in avoiding the undesirable effects of the higher levels. Secondly, another low level implantation was to be given during the experiment to determine if an additional growth stimulus would result.

Experiment I

Experimental Procedure

Fifty grade Angus and Hereford steers were divided into five lots of 10 steers each with the animals in each lot receiving a different

[1] The authors are grateful to White Provision Co. of Atlanta for making possible the collection of carcass data.

[2] The stilbestrol used in the experiment was furnished by Wick and Fry, Inc. through the courtesy of W. S. Davidson.

[3] Contribution from the Department of Animal Husbandry, Athens. Journal Paper No. 20 of the College Experiment Station. Prepared from M.S. thesis of H. H. Pierce, Jr. and one additional experiment.

ration. Five steers in each lot or a total of 25 steers were chosen by stratified randomization to receive 36 mg. of stilbestrol per steer implanted subcutaneously in the ear. The other 25 served as controls. After a period of 42 days two of the five treated steers in each lot received an additional 36 mg. of stilbestrol. Eighty-five days after initial treatment five judges scored the steers on straightness of top line. At the time of slaughter, data on seminal vesicle weight, carcass grade and dressing percentage were obtained.

Results and Discussion

Daily Rate of Gain. The average daily rates of gain for the control and treated groups during each of two periods and for the total 105-day test are shown in table 1.

TABLE 1. THE EFFECTS OF STILBESTROL ON THE RATE OF GAIN IN STEERS

Period	Treatment	No. of animals	Initial wt.	Daily gain
			lb.	lb.
First (42 days)	Control	24[a]	752	1.88
	36 mg. Stilbestrol (Initially)	25	716	2.26**
Second (63 days)	Control	24	831	.97
	36 mg. Stilbestrol (Initially)	15	797	1.38**
	36 mg. Reimplanted (On 42nd day)	10	832	1.41**[b]
Total (105 days)	Control	24	752	1.34
	36 mg. Stilbestrol (Initially)	15	701	1.74**
	36 mg. Reimplanted	10	739	1.74**[b]

** Significant at 1 percent level.
[a] One extremely wild steer was removed from test.
[b] No significant difference between the steers initially implanted and those reimplanted.

During the first period of 42 days the control steers gained 1.88 lb. per steer per day while the treated steers gained 2.26 lb. The increase of .38 lb. represented a highly significant difference. During the second period or the remainder of the test the control steers gained .97 lb. per head daily, the initially treated animals gained 1.38 lb. and those reimplanted gained 1.41 lb. Although both treated groups had highly significant increases in daily gains over the controls they did not differ significantly from each other. Over the entire test the treated animals gained 1.74 lb. per steer daily compared to 1.34 lb. for the controls.

The difference of .40 lb. in favor of the treated groups was highly significant. From the results of this experiment reimplanting 36 mg. of stilbestrol at 42 days did not give an additional growth stimulus.

Topline Scores. On the 85th day after hormone treatment a committee of five judges rated the steers on straightness of topline. To facilitate analysis of the data, numerical values were assigned as follows: 1, level topline; 2, slight depression of the loin; 3, marked depression of the loin. The average topline scores for the control, initially treated, and reimplanted steers were 1.59, 2.40 and 2.10, respectively (table 2). An analysis of the data shows the difference between the treated and control groups to be highly significant with no significant difference between the two treated groups. This indicates that as low as 36 mg. of stilbestrol will cause the loins of steers to be depressed.

TABLE 2. EFFECTS OF STILBESTROL ON TOPLINE SCORES, SEMINAL VESICLE WEIGHTS, CARCASS GRADES AND DRESSING PERCENTAGES

	Control	Stilbestrol 36 mg.	Reimplanted 36 mg. stil.
Topline scores	1.59	2.40**	2.10**[a]
Seminal vesicle wt., gm.	5.84	12.63**	13.37**[a]
Carcass grade	11.17	10.13	10.70
Dressing percent	56.4	55.9	57.2

** Significant at 1 percent level.
[a] No significant differences between the initially implanted and those reimplanted.

Dinusson *et al.* (1950) found a similar condition in heifers which they referred to as elevated tail heads.

Seminal vesicle weights. The average seminal vesicle weights (one seminal vesicle taken from each steer) were 5.84, 12.63 and 13.37 gm. for the control, initially implanted, and reimplanted groups, respectively. There was no significant difference between the two treated groups in seminal vesicle weights but in both groups the average weights were increased highly significantly over the controls. The mean seminal vesicle weights are presented in table 2. Increased size of secondary male tissue has been regarded as undesirable in certain instances. Ruliffson *et al.* (1954) indicated that in lambs the male accessory organs may be enlarged to such an extent as to interfere with normal urination which in turn may cause death. Although the seminal vesicles were enlarged in steers in this test, there were no indications of any abnormal urination at any time.

Dressing Percentages. The average dressing percent was 56.4 for the

controls, 55.9 for the initially treated and 57.2 for the reimplanted. These values (shown in table 2) were not significantly different.

Carcass Grades. Table 2 shows the average carcass grades, as represented numerically, of the three groups of steers. The system of scoring the carcasses was as follows: 8, average utility; 9, top utility; 10, low commercial; 11, average commercial; 12, top commercial; and 13, low good. There were no significant differences between treated and control groups.

The results obtained from steers showed that both carcass grades and dressing percentages were not significantly affected by the low level of stilbestrol and are in agreement with those reported by Dinusson *et al.* (1950) in heifers.

Experiment II

Experimental Procedure

Fifty good and commercial feeder steers were divided into five lots of 10 steers each. Within each lot the steers were subdivided so that five of the steers served as controls and the other five were implanted in the ear with a total of 36 mg. of stilbestrol per steer. In an attempt to confirm previous results (O'Mary *et al.* 1953), three of the steers in each lot received 36 mg. of stilbestrol as in Experiment I. Since the reimplanted steers in Experiment I failed to give an added response, in Experiment II the dosage level was lowered so that the other two steers in each lot received 12 mg. initially and an additional 24 mg. after eight weeks. The total number of steers in each treatment group, therefore, was 25 controls, 15 receiving 36 mg. initially and 10 steers getting 12 mg. initially and 24 mg. later. The weights of the steers were taken at two-week intervals. The topline scores were taken as described in Experiment I except observations were made after 65 days on test rather than 85 days.

Results and Discussion

The daily rate of gain of the steers for the first eight weeks was 1.54, 1.65 and 2.08 lb. for the controls, 12 mg. plus 24 mg. group and 36 mg. group, respectively. Analysis of the data indicated no significant difference between the controls and those getting 12 mg. of stilbestrol. However, those steers getting 36 mg. made a significant average daily increase of .54 lb. per steer over the controls. The results obtained in Experiment II by implanting 36 mg. of stilbestrol confirmed those

obtained in Experiment I in that rates of gain were significantly increased by treatment.

During the second eight weeks the control steers gained an average of 1.66 lb. per head daily. In the group which received an additional 24 mg. of stilbestrol at the beginning of the second period the daily rate of gain was 1.99 lb. and the difference from the control represents a highly significant increase. The group receiving 36 mg. maintained its rate of gain at 2.02 lb. and was not significantly different from the other treated group during this period.

TABLE 3. EFFECT OF STILBESTROL ON RATE OF GAIN AND TOPLINE SCORES OF FATTENING STEERS

Group	Control	Stilbestrol implants	
		12–24 mg.	36 mg.
No. of animals	25	10	15
Av. initial weight, lb.	485	478	473
Av. daily gain:			
1st 8 weeks, lb.	1.54	1.65[a]	2.08*
2nd 8 weeks, lb.	1.66	1.99**[b]	2.02**
Final 4 weeks, lb.	1.81	1.97	1.95
Total of 140 days, lb.	1.64	1.85	2.03
Av. total gain, lb.	230	259	284
Increase over controls, lb.	...	29	54
Av. topline scores	1.78	1.96*	2.04*

[a] 12 mg. stilbestrol were implanted initially.
[b] An additional 24 mg. stilbestrol was implanted at the beginning of the 2nd 8-week period.
* Significant at 5 percent level.
** Significant at 1 percent level.

In the final 4-week period the rates of gain for the treated groups remained about the same as during the previous period but the controls increased enough so that there was no significant difference between the three groups. The rates of gain made by the steers over the entire 140 days were 1.64, 1.85 and 2.03 lb. for the control group, 12 mg. plus 24 mg. group and the 36 mg. group, respectively.

The group of steers receiving 36 mg. of stilbestrol initially gained .39 lb. more per head daily than the controls, this difference being highly significant. Since there was no difference in daily gain during the first period between controls and the group receiving 12 mg., over the entire test this treated group was handicapped. On the basis of this test it is not known whether 24 mg. would be effective if implanted

at the same time as the 36 mg. If one assumes no carry-over effect of 12 mg. into the second period, then 24 mg. were shown to be effective over at least an 8-week period and may be near the minimum effective dose for steers.

The topline scores as indicated in table 3 revealed that the loins of the treated steers were significantly lower than the controls at 65 days after initial treatment. This may be of significance and may influence the buyer if still evident at the time of selling the steers. Andrews *et al.* (1954) believes this condition to return to normal with time but in some cases may still be noticeable as long as 182 days after treatment.

Summary

Two experiments were conducted on the effects of low level implantation of stilbestrol in steers. Each experiment involved 50 steers.

In the first experiment of 105 days duration, 36 mg. of stilbestrol implanted in the ear resulted in a highly significant increase in rate of gain for the treated steers when compared to controls. An additional 36 mg. implanted at 42 days failed to give an additional growth stimulus. The seminal vesicle weights were increased in steers treated with stilbestrol. However, there were no significant differences between the treated and control groups in either carcass grade or dressing percentage.

In Experiment II the daily rate of gain of steers treated with 36 mg. of stilbestrol was significantly higher than for the control steers over the first 8 weeks, but 12 mg. of stilbestrol had no significant effect. During the second 8-week period an additional 24 mg. following the initial 12 mg. resulted in increased daily gains over the controls. The difference was highly significant. The final results of Experiment II over the 140 days showed a highly significant difference in rate of gain between steers treated with 36 mg. of stilbestrol and controls but no significant difference between the 12 plus 24 mg. treated steers and controls.

The treated steers showed a depression of the loin at 85 days and 65 days for Experiments I and II, respectively.

Literature Cited

Andrews, F. N., W. M. Beeson and F. D. Johnson. 1954. The effects of stilbestrol, dienestrol, testosterone and progesterone on the growth and fattening of beef steers. JOURNAL OF ANIMAL SCIENCE 13:99.

Braude, R. 1950. Stimulation of growth in pigs by iodinated casein and stilbestrol. British Jour. Nutr. 4:138.

Clegg, M. T., H. H. Cole and H. R. Guilbert. 1951. Effects of stilbestrol on beef heifers and steers. JOURNAL OF ANIMAL SCIENCE 10:1074.

Dinusson, W. E., F. N. Andrews and W. M. Beeson. 1950. The effects of stilbestrol, testosterone, thyroid alteration and spaying on the growth and fattening of beef heifers. JOURNAL OF ANIMAL SCIENCE 9:320.

Kochakian, Charles D. 1947. Effects of estrogens on the body and organ weights and the arginase and "alkaline" and "acid" phosphatases of the liver and kidney of castrated male mice. Am. Jour. Physiol. 151:126.

O'Mary, C. C., E. P. Warren, T. J. Davis and H. H. Pierce. 1953. The effect of stilbestrol on the performance of fattening steers fed blackstrap molasses. JOURNAL OF ANIMAL SCIENCE 12:952.

Ruliffson, W. S., T. D. Bell, J. S. Hughes and A. Nunn. 1954. Neutral 17-ketosteroids in the urine of normal and diethylstilbestrol treated wether lambs. JOURNAL OF ANIMAL SCIENCE 13:1030.

PERFORMANCE AND GRAZING HABITS OF HEREFORD AND ABERDEEN-ANGUS COWS AND CALVES ON IMPROVED PASTURES AS RELATED TO TYPES OF SHADE

A. H. McDaniel and C. B. Roark [1]

Louisiana Agricultural Experiment Station [2]

Worstell and Brody (1953) suggest that there is more urgent need for developing methods for protecting cattle against rising temperatures above 80° F. than against declining temperatures below freezing. Experiments conducted at the Mississippi Agricultural Experiment Station (1953) showed that steer yearlings of Angus breeding on pastures with natural or artificial shade in July and August will make better gains than steers on pastures without shade. However in work conducted at the Oklahoma Station (1954), artificial shade had little apparent effect on either Hereford cows or calves. Kelly (1948) and Ittner (1951) found that the type or kind of artificial shade, with reference to shade height and kind of roof, had a decided effect in lowering the radiant heat load on the animals standing in the shadow. The tests reported here were conducted to compare the performance and grazing habits of Hereford and Angus cows and calves grazing improved pastures with different types of shade and without shade. The primary objective of this study was a shade comparison rather than a breed comparison.

Experimental Procedure

This study was made at the West Louisiana Experiment Station in the cut-over pine lands of West Louisiana. The study covered a 4-year period beginning in 1951 and continuing through 1954. Data for the study were collected from 81 test groups involving approximately 100 head per year of registered and grade Hereford and Angus cows with calves. There were 61 test groups grazing the pastures with shade and 20 test groups grazing the pastures without shade. The test periods averaged 25 days in length and the average number of cattle per test was 6 head of cows with calves. Angus cows and calves made up 40 percent of the cattle used and Herefords comprised the

[1] We acknowledge with thanks the counsel of Dr. M. T. Henderson on the statistical analysis of the data.

[2] Baton Rouge, Louisiana.

remainder. Registered Hereford and Angus cows and calves made up 27 percent of the cattle. The grade Hereford and Angus cattle were of high quality and were representative of the breeds. The collection of data began each year as soon as symptoms of climatic stress were evident. Usually these symptoms were noticeable about April 15 and continued through the summer months.

The treatments consisted of pastures with (1) abundant natural shade, (2) scanty natural shade, (3) artificial shade, and (4) without shade. The abundant natural shade was from groups of trees consisting predominately of gum, oak, and bay. The scanty natural shade consisted of scattered pine trees and pine saplings, and some small oak trees. The artificial shades had roofs of hay, straw, or pasture clippings. The roofs were 12 ft. by 24 ft., and 7 ft. above the ground. These roofs supported by net wire were approximately 6 in. thick.

The pastures were comparable except for the shade differences. However, the cattle were generally rotated to different pastures and treatments at the end of each test period in an effort to eliminate possible pasture differences.

The influence of the four different treatments on grazing habits was determined by observing the cattle hourly from 6 a.m. until 7 p.m. (13 hours), noting the time spent grazing, standing, and lying.

The mean 4-year maximum temperature and percent relative humidity during the trials were taken with standard U. S. Weather Bureau equipment located on the station. The temperature readings at the treatment areas were taken 3 ft. from the ground, an equal number of readings being taken in the shade and in the sun.

Results and Discussion

The results in table 1 are averages for 4 years. Gains made by the cows on the abundant shade and scanty shade treatments were significantly greater than those made by the cows without shade; however, the gains made by the cows on the artificial shade treatment were not. Calves on all three shade treatments made significantly greater gains than calves without shade.

There was a close relationship between the type or kind of shade and the amount of time cows spent grazing, standing, and lying. This relationship, was less apparent with the calves.

The time spent grazing by the cows was greatest on the abundant shade treatment and decreased with decreased shade through the without shade treatment (table 1). The time spent standing was greatest

TABLE 1. EFFECTS OF TYPE OF SHADE ON PERFORMANCE AND GRAZING HABITS OF HEREFORD AND ABERDEEN-ANGUS COWS AND CALVES (4-Year Summary, 1951–1954)

Treatment	Abundant natural shade		Scanty natural shade		Artificial shade		Without shade	
Class	Cows	Calves	Cows	Calves	Cows	Calves	Cows	Calves
Number	255	255	110	110	40	40	112	112
Av. weight, lb.	1013	336	1037	349	990	354	960	322
Av. daily gain, lb.	1.29**	1.85**	1.00*	1.64*	0.84	1.78*	—.05	1.18
Grazing habits (6 a.m.-7 p.m.)								
Grazing, hr. and min.	4:16	3:05	4:13	2:45	3:58	3:06	3:47	2:42
Standing, hr. and min.	4:16**	4:00**	4:30**	4:03**	4:55*	3:49**	6:04	5:06
Lying, hr. and min.	4:28**	5:55*	4:17**	6:12**	4:07*	6:05*	3:09	5:12
Number of tests	30	30	19	19	12	12	20	20
Av. days on test	27.6	27.6	22.7	22.7	25.6	25.6	21.7	21.7
Av. number per test	8.5	8.5	5.8	5.8	3.3	3.3	5.6	5.6
Av. maximum temperature, degrees F.	89.6	89.6	91.4	91.4	88.4	88.4	86.9	86.9
Av. relative humidity, %	63.1	63.1	62.4	62.4	62.8	62.8	64.0	64.0

*, ** Values significant different, 5 percent and 1 percent level, respectively, from those of the without shade treatment.

on the without shade treatment and least on the abundant shade treatment. The time spent lying was greatest on the abundant shade treatment.

The lack of a statistically significant difference in grazing time between any of the treatments for either the cows or the calves during the observation period was probably due to night grazing. Miller *et al.* (1951) working with dairy cattle failed to find a significant difference in grazing rate between treatments.

Cattle on pastures without shade indicated a need for shade by panting, excessive walking and standing, reduced rumination, crowding in fence corners, frequent drinking and lying down in the late afternoon after the temperature had lowered. In contrast, the cattle on pastures with shade started grazing at approximately the same time

TABLE 2. RELATION OF TREATMENT AND TEMPERATURE TO AVERAGE DAILY GAINS (4-Year Summary, 1951–1954)

Treatment comparison	Av. max. temp. range degrees F.	Temp. diff. degrees F.	Diff. in av. daily gain, lb.	
			Cows	Calves
Without shade vs. abundant shade	96.8–90.7	6.1**	1.34**	0.67**
Without shade vs. scanty shade	96.8–93.5	3.3**	1.05*	0.46*
Without shade vs. artificial shade	96.8–93.0	3.8**	0.89	0.60*
Scanty shade vs. abundant shade	93.5–90.7	2.8**	0.29	0.21
Artificial shade vs. abundant shade	93.0–90.7	2.3**	0.45	0.07
Scanty shade vs. artificial shade	93.5–93.0	0.5	0.16	0.14

*, ** Significant at 5 and 1 percent level, respectively.

the cattle without shade started lying down. These visual symptoms of climatic stress were more pronounced during the late spring than during the summer. This is in agreement with the findings of Kibler and Brody (1949) that rapid changes in environmental temperature tended to accentuate functional response, and that acclimatization of heat production and pulse rate levels to extreme changes in environmental temperatures required as much as 4 weeks under some conditions.

The amount of shade available per animal unit on the artificial shade treatment was 32 sq. ft. However, recent studies by Ittner *et al.* (1954) suggest at least 60 sq. ft. of shade is needed per animal (750–1050 lb.) and that because of radiation effects, the shades should be 10–12 ft. above ground. The lack of these conditions undoubtedly contributed to the poor performance of the cows grazing the pastures with artificial

shade. The small area of shade available per animal unit also created a sanitation problem.

Calves were less affected by the various treatments than were the cows, as measured by gains and grazing habits. Cows responded about twice as well to the shade treatments as did the calves. A possible explanation of this difference is that the greater surface area of the calves per unit weight may have enabled them to dissipate heat at a greater rate than the cows.

Summary

The results of 4 years of tests to determine the effects of different shade types on the performance and grazing habits of Hereford and Aberdeen-Angus cows and calves are reported.

Cows grazing pastures with either abundant or scanty natural shade made significantly greater gains than cows grazing pastures without shade; cows grazing pastures with artificial shade did not. Calves grazing the pastures with either abundant, scanty, or artificial shade made significantly greater gains than calves grazing pastures without shade.

Calves were less affected by the different treatments than were the cows, as measured by gains and grazing habits.

The observed standing and lying time but not the time spent grazing was significantly influenced by the shade treatments for both cows and calves.

Daily gains and general comfort of Hereford and Angus cows and calves at this Station were materially increased during late spring and summer by providing the right kind of shade.

Literature Cited

Ittner, N. R. and C. F. Kelly. 1951. Cattle shades. JOURNAL OF ANIMAL SCIENCE 10:184.

Ittner, N. R., T. E. Bond and C. F. Kelly. 1954. Increasing summer gains of livestock. JOURNAL OF ANIMAL SCIENCE 13:867.

Kelly, C. F. and N. R. Ittner. 1948. Artificial shades for livestock in hot climates. Agr. Eng. 29:239.

Kibler, H. H. and Samuel Brody. 1949. Environmental physiology. Mo. Agr. Exp. Sta. Res. Bul. 450.

Miller, G. D., J. B. Fyre, Jr., B. J. Burch, Jr., P. J. Henderson and L. L. Rusoff. 1951. The effect of sprinkling on the respiration rate, body temperature, grazing performance, and milk production of dairy cattle. JOURNAL OF ANIMAL SCIENCE 10:961.

Miss. Agr. Exp. Sta. Sixty-Sixth Annual Report. 1953. p. 58, Feeding and Breeding Tests. 1954. Okla. Agr. Exp. Sta. Misc. Pub. No. MP-34, p. 71.

Worstell, D. M. and Samuel Brody. 1953. Environmental physiology and shelter engineering. Mo. Agr. Exp. Sta. Res. Bul. 515.

FURTHER STUDIES ON THE UTILIZATION OF ALFALFA BY BEEF STEERS

J. H. Meyer, G. P. Lofgreen and N. R. Ittner

University of California [1, 2]

THERE is a paucity of available information on comparative beef production from soiling, haying, and pasturing alfalfa. There is no information available on the amount of forage consumed by animals on pasture when compared to animals fed harvested forage either as hay or soilage. The recent discovery of Reid *et al.* (1950), that the digestibility of forage can be determined from the concentration of plant pigments (chromogens) in the feces, makes available a method for calculating the forage consumption by steers on pasture if the total dry matter excreted in the feces is determined.

In a previous report from this Station (Ittner *et al.*, 1954) the existing information on the comparative value of soiling and pasturing was reviewed. It was found that, in comparison with 8 to 12-day rotational grazing, soiling and 1-day rotational grazing increased beef production 69 and 39 percent, respectively. This was the first report on comparative production from soiling and pasturing of the same forage. It would be desirable to have information also on comparisons with haying, since some beef feed-lots and dairies are replacing hay with soilage. Since the above workers did not obtain forage consumption of the animals on pasture and since comparisons were not made with forage fed as hay, experiments were designed to obtain this information.

Experimental

Two experiments were conducted to compare the beef production from rotational grazing, either strip grazing or 1-day rotational grazing, haying, and soiling of alfalfa. Separate locations were used for each experiment to obtain information under different conditions.

Experiment 1

This experiment at the Imperial Valley Field Station of the California Agricultural Experiment Station was conducted in essentially the same

[1] Department of Animal Husbandry, Davis, California.

[2] The authors express their appreciation to M. L. Peterson, Department of Agronomy for his advice on the design and conduct of the experiment; P. R. Trask and D. Gaskin for their care of the animals at the Imperial Valley Field Station; J. L. Hull and Ralph Arthur for the management of the field and animals at Davis; and J. D. Smith for the chromogen analyses.

manner as that reported by Ittner *et al.* (1954). The design is shown in table 1. There were two deviations in this experiment. First, the rotational pasture was grazed for 7 days rather than for 8 to 12 days. Secondly, a comparison was made to steers fed hay which was harvested at approximately one-tenth bloom stage from a field comparable to that used by the soilage and pasture lots. Accurate records were kept of the yield of hay.

Experiment 2

A second experiment was conducted at the University Farm at Davis during the months of May through September. It consisted of a more elaborate design than that used in Experiment 1. As in Experiment 1,

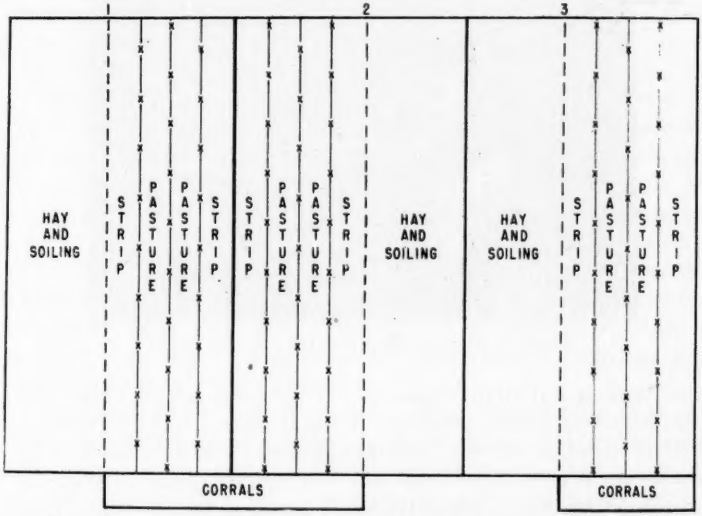


Figure 1. Layout of pasture.

four treatments were used—rotational grazing, strip grazing, haying, and soiling. Forty head of good to choice feeders were divided at random into four lots of ten head each and assigned to the four experimental treatments. The layout of the alfalfa field is shown in figure 1. An uniform field of alfalfa was selected and divided into three blocks and the treatments randomized within each block. An over-all view of block 2 is shown in figure 2. The animals were in each block for either a 10 or 12-day

period. The steers were weighed when moved from one block to the next. Before each weighing, steers were shrunk 14 hours without feed or water.

Prior to the beginning of the experiment, the first cutting was harvested and not used for the experiment. This first cutting was harvested 30, 20, and 10 days before the experiment was to commence from blocks 1, 2, and 3 respectively. This was done so that as the experiment progressed from one block to another the forage would be approximately the

Figure 2. View of Block 2 in the pasture layout.

same stage of maturity. For example, as the steers entered block 1 for the first 10-day grazing period the forage in block 1 had been growing 30 days while that in block 2 had been growing for 20 days. Then as the steers entered block 2 the forage had been growing 30 days. During the experiment, the forage was harvested or grazed at the one-tenth bloom stage or earlier. The fields were irrigated every 15 days.

Alfalfa that was to be fed as hay was mowed at the same time as the pasture and soilage was grazed or fed. Generally, it took about 7 days for the alfalfa hay to be cured and baled. Because of this, the animals fed alfalfa hay during a given period received hay harvested from the previous period. Accurate records were kept on yield and dry matter. Hay curing conditions were excellent thus allowing the making of good quality hay throughout the experiment.

The rotational pasture animals were in each block for 10 or 12 days

but 2 fields were used for pasture within each block. This gave a 5 or 6 day pasture rotation and allowed longer periods for the alfalfa to recover than if the pasture was rotated every 10 or 12 days. Through the use of an electric fence the area of the pasture allowed the animals was adjusted to a size that the animals could clean up in a satisfactory manner. All pasture that was refused because of trampling was mowed, raked and hauled from the field at the end of each period.

The method used for strip grazing in this experiment would meet the true definition of the term. The animals were given a strip of forage 670 feet long and not more than 2 or 3 feet wide at any one time. By this means, the animals were receiving their forage in a long narrow strip as if it was offered to them in a long manger or feed bunk and, consequently, trampling of the forage was kept to a minimum. As far as could be observed the feces and most of the urine fell on an area which had been previously grazed. This can be observed in some detail in figure 2. The electric fence was moved once or twice daily depending upon the speed with which the animals grazed the 2 or 3 foot strip. This operation, even though the strip was 670 feet long, took approximately 15 minutes. As with the rotational pasture lot, the strip grazing group was given two pasture areas within each pasture block. When a new pasture was opened for strip grazing, an area 5 feet wide was harvested by a forage harvester along the fence to give the steers an area for grazing without trampling fresh forage. This area was not used in the calculation of the area grazed. Admittedly, this method of strip grazing is not adaptable to practical conditions where larger herds of animals are handled, but was used in order to ascertain if an optimum method of strip grazing would approach the productivity of the soiling method.

The dry lot steers were fed hay or soilage twice daily. Soilage was harvested twice daily by a field forage harvester, weighed, and sampled for dry matter analysis. At the beginning of the experiment, a small amount of oat hay was fed to the steers on pasture and soilage so that maximum utilization of the green alfalfa might result. Serious bloating, however, did occur and one steer was lost from bloat. Due to this trouble with bloat, the oat hay was increased to 4 to 5 lb. per head per day. This level effectively controlled the bloat. Bloat was a lesser problem with the soilage steers than with either pasture group. Actually greater trouble was experienced with the strip grazing animals since they received a fresh pasture daily.

During the last 100 days of the experiment a total collection of feces was made from three steers in each lot which earlier had been trained to

lead and tolerate fecal collection harnesses. Four days after entering a new block, feces were collected for 5 or 6 days. This allowed sampling of the feces which resulted from each block. By this procedure feces were collected for 50 of the 100 days. Collections were made once daily, weighed and sampled for dry matter and chromogen analyses.

The chromogen analysis used was that described by Reid *et al.* (1952). Preliminary work with the chromogen method indicated essential agreement with the results obtained by Lancaster (1954), in which he found that the chromogen extracted in dim light and stored in the dark increased in light transmission. He also found that the chromogen extract, if exposed to a standard amount of light, would not change in transmission if stored in the dark. Therefore, the following procedure was used for the chromogen analysis. The feces were extracted as described by Reid *et al.* (1952), and immediately the chromogen extract was exposed to 800 foot candles of light for a period of 20 minutes. This fixed the chromogen solution so that little change in light transmission occurred if stored in the dark. The same procedure was used when establishing a standard curve. Through the courtesy of Dr. Reid, readings were made in his laboratory on this standard. By this means, then, the standard curve used in this experiment could be adjusted and the regression equation established by Reid *et al.* (1952) for calculating the digestibility of forage from the chromogen concentration in the feces could be used.

It was found in this experiment that the alfalfa hay did not contain sufficient amounts of chromogen to give a concentration in the feces within the range of the curve used by Reid *et al.* (1952) in calculating digestibility. In order to circumvent this problem, samples of hay which were fed to the steers of the hay lot were saved throughout the trial. At the end of the trial, four wethers were used for digestibility determination on this hay. The digestibility figures thus obtained were applied to the total amount of dry matter excreted by the three steers in the hay lot so that individual feed consumpiton could be calculated.

When the amount of beef produced from the alfalfa forage alone was calculated, adjustments were made for the oat hay consumed. Composite samples of the soilage and oat hay were saved and TDN was determined on these samples with sheep at the termination of the trial. The TDN consumption from the soilage and oat hay could then be used to apportion the total beef production to that produced from soilage and oat hay. For the pasture animals it was assumed that the same gain would occur per unit of oat hay consumed as that found for the animals fed soilage. Corrections could be made for the gains due to oat hay and subtracted

from the total beef produced to obtain the beef produced from alfalfa pasture alone.

Analysis of variance (Snedecor, 1946) was used for the statistical analysis and the method of least significant difference was used to determine significance between treatments.

Results and Discussion

Experiment 1

A summary of the results from the experiment conducted at the Imperial Valley Field Station (table 1) shows essential agreement with those

TABLE. 1. PASTURE STUDIES, IMPERIAL VALLEY FIELD STATION

	Pasture lots		Dry lots	
	7-Day rotation grazing	1-Day rotation grazing	Haying	Soiling
No. of steers	10	10	10	10
Days on experiment	155	155	155	155
Initial wt., lb.	479	480	480	480
Av. daily gain, lb.	1.94	1.70	1.67*	1.80
Feed consumption per head per day				
As fed				
Forage, lb.	..	..	16.8	55.0
Oat hay, lb.	2.9	4.0	..	3.1
Dry basis				
Forage, lb.	..	..	16.3	11.5
Oat hay, lb.	2.8	3.9	..	3.0
Dry matter per 100 lb. gain, lb.	..	..	976	806
Beef production per acre				
Pounds	525**	539**	576**	678
Percentage of soiling	77	79	85	100
Percentage of rotational grazing	100	103	111	129

* Significant at the 5 percent level when compared to soiling.
** Significant at the 1 percent level when compared to soiling.

reported earlier (Ittner *et al.*, 1954). The average daily gains were excellent for animals fed an all roughage diet. Even though the total dry matter consumed by the hay lot was greater than that consumed by the steers in the soiling lot, the average daily gains were lower for these animals. This was reflected in an increase in the amount of feed required per 100 lb. of gain for the steers fed hay.

Values given for beef production per acre have been corrected for the oat hay consumed and represent that amount consumed for the alfalfa

forage alone. For comparative purposes, beef production per acre was expressed as a percentage of the amount produced by the soiling and also as a percentage of that produced by the rotational grazed lot. It is thought, however, that the former method of comparing beef production per acre for various methods of forage utilization is more consistent for comparative purposes because the soiling operation can be more consistently managed. If the pasture lots are used as a standard for comparison, greater variation from one experiment to another may occur because of differences in the length of rotation interval and the number of animals carried per acre.

In this experiment, little difference was obtained between 7-day and 1-day rotational pasture in terms of gains and beef production per acre. This is not in agreement with the results of Holmes *et al.* (1952) with dairy cows. Neither does it agree with results obtained by Ittner *et al.* (1954). The main difference between the latter work and this experiment was the change from the 8 to 12-day interval to a 7-day interval for the rotational pasture. In these studies, nothing was gained in shortening the rotational interval to less than 7 days.

Rotational grazing produced 77 percent the amount of beef per acre of that by soilage. Ittner *et al.* (1954) showed that rotational grazing produced 59 percent that of soilage. A shorter rotational interval in this experiment may explain the difference.

It is interesting to note that practically equal amounts of beef were produced per acre from soiling and 1-day rotational pasturing in the study by Ittner *et al.* (1954) and in this experiment. Both experiments, although conducted during succeeding years, were conducted in the same season and in the same fields. To compare the results a common denominator of beef produced per acre per day is used because of a difference in the length of the experimental period. In the report cited above, 3.45 and 4.19 lb. of beef were produced per acre per day by the 1-day rotational pasture lot and by the soiling lot respectively, while in this experiment 3.48 and 4.37 lb. were produced, respectively.

The amount of forage dry matter produced by haying was about the same as that produced by soiling. Haying, however, produced 85 percent the amount of beef. This can probably be attributed to the loss of leaves and fine stems in the haying operation.

Experiment 2

The results obtained at Davis, (table 2) agree well with those of the Imperial Valley Field Station (table 1). The daily gains were the same

for the soilage and pasture lots but as noted in the first experiment, there is a decrease in the average daily gain of the steers fed hay. When both groups of data were combined, it was found that the decrease in daily gains for the hay lots was statistically significant.

The amount of beef produced per acre by the 5-day rotational pasture was 64 percent of that produced by the soilage group. The beef production per acre for the soilage group in comparison with the pasture lot was

TABLE 2. PASTURE STUDIES, DAVIS

	Pasture lots		Dry lots	
	5-Day rotation grazing	Strip grazing	Haying	Soiling
No. of steers	9	9	10	10
Days on experiment	132	132	132	132
Initial wt., lb.	550	565	574	532
Av. daily gain, lb.	1.79	1.64	1.45*	1.73
Feed consumption per head per day				
As fed				
Alfalfa, lb.	..	..	21.4	69.0
Oats, hay, lb.	4.7	4.9	..	3.9
Dry basis				
Alfalfa	..	..	18.9	14.1
Oat hay, lb.	4.2	4.4	..	3.5
Dry matter per 100 lb. gain, lb.	..	..	1303	1017
Beef production per acre				
Pounds	689**	739**	856**	1080
Percentage of soiling	64	68	79	100
Percentage of rotational grazing	100	107	124	157

* Significant at the 5 percent level when compared to soiling.
** Significant at the 1 percent level when compared to soiling.

relatively greater in Experiment 2 than in Experiment 1. This difference might be attributed primarily to the more luxuriant growth of alfalfa at Davis than in the Imperial Valley which would allow more of a trampling loss for the pasturing animals. It would seem probable that a relatively greater increase in beef production could be expected from soilage in an area where the forage is taller and more productive.

Even though an elaborate strip grazing procedure was practiced, beef production per acre from strip grazing differed little from the results of the 5-day rotational grazing. These results are in agreement with Experiment 1.

Haying produced 124 percent as much beef per acre as rotational grazing. This was true even though the average daily gains were less for the steers fed hay. This can be attributed to a greater production of forage dry matter per acre from hay than that produced by pasturing (table 4). This increase in production of forage dry matter over the pasturing was enough to offset the decrease in daily gains and show an increase in production of beef per acre. The decrease in daily gains of the steers fed hay, however, resulted in a lowered beef production per acre compared to the soiling group, because practically equal amounts of forage dry matter were produced per acre by these two groups.

TABLE 3. RESULTS FROM STEERS ON COLLECTION

	Pasture lots		Dry lots	
	Rotation grazing	Strip grazing	Haying	Soiling
No. of steers	3	3	3	3
Days on experiment	100	100	100	100
Av. daily gain, lb.	1.62	1.42	1.13*	1.40
Feed consumption daily, dry basis				
Alfalfa, lb.	9.1	7.8*	19.0*	11.2
Oat hay, lb.	4.8	5.0	...	3.8
Feed per 100 lb. gain, lb.	864	902	1679	1073

* Significant at the 5 percent level when compared to soiling.

The results obtained from the three steers used in each lot for the collection of feces are shown in table 3. The average daily gains were significantly less in all cases from that of the steers not on collection. Even though the steers were well trained before the experiment commenced, the weight of the harness and feces which often amounted to 70 to 80 lb., undoubtedly had a detrimental effect on feed consumption and gains. These animals were the last to graze or eat at the feed bunkers and the first to lie down. However, the average daily gains were still in the same order as those noted for the entire group of steers. Here again the smaller daily gain due to the hay feeding was statistically significant when compared to the other lots.

The consumption of forage presents some interesting comparisons. First, the steers on rotational grazing consumed about 13.9 lb. of dry matter and yet gained at the same rate as the steers fed soilage with an intake of 15 lb. This was also true for those on strip grazing when compared to the soiling lot. This evidently means that the forage consumed

by the soilage steers did not have as high a nutritive value as that of the pasture steers. This indicates to some extent the increase in nutritive value caused by selective grazing by the steers on pasture. Hardison *et al.* (1954) observed this phenomenon in terms of digestibility and quality of forage consumed.

The forage consumption of the collection steers was used to calculate the total amount of alfalfa forage consumed per acre for the entire group of steers. Since the steers on collection gained at a lower rate than those not on collection, it was necessary to make an adjustment in feed consumption. This was done by calculating the amount of TDN required for maintenance and gain through the use of the equation presented by Winchester (1953). Since feed consumption of the steers on collection

TABLE 4. RESULTS FROM THE APPLICATION OF THE DATA OF THE COLLECTION STEERS

	Pasture lots		Dry lots			
	Rotation grazing	Strip grazing	Haying		Soiling	
Days on experiment	100	100	100		100	
Ave. daily gain, lb.	1.75	1.54	1.34		1.64	
Beef produced per acre, lb.	503	503	569		733	
Total feed consumption	Calcu.	Calcu.	Meas.	Calcu.	Meas.	Calcu.
Alfalfa, lb.	9162	8063	19427	19679	13877	12934
Oat hay, lb.	4360	4507	....	....	3825	3825
Daily feed consumption						
Alfalfa, lb.	10.2	9.0	19.4	19.7	13.9	12.9
Oat hay, lb.	4.8	5.0	....	....	3.8	3.8
Feed per 100 lb. gain, lb.[a]	859	907	1450	1469	1079	1022
Forage consumed acre, lb.[a]	3743	3957	7130	7223	7395	6893

[a] Oven-dry basis.

was known, it was possible to calculate the TDN content of the feed consumed by dividing the TDN required for maintenance and gain by the feed consumed. The amount of feed required to furnish the TDN necessary to produce the observed gains of all steers was then determined. The total feed consumed by the entire lot of steers for the 100-day collection period is in table 4. Very excellent checks were obtained in the measured feed consumption for the hay lot when compared with the calculated feed consumption. About a 6 percent difference was noted in the measured dry matter consumed by the soiling lot and the calculated dry matter consumed. This difference is well within the biological variation for this experiment. Part of this difference might be accounted for by the feed dropped on the ground by the steers leaving the mangers with a mouth

full of forage. This points out that in pasture studies it seems possible that accurate data on feed consumption can be predicted when approximately one-third of the animals are used for collection of feces in order to calculate feed consumption by this method.

The amount of forage consumed per acre calculated by the above described method points out that the forage consumption for the pasture lots amounted to 52 percent that found for the steers fed soilage. This means that a great deal of forage was trampled and lost or refused by the animals on pasture. As noted above, however, selective grazing results in the consumption of a more nutritious feed for animals on pasture. Therefore, when a more nutritious feed was consumed by steers on pasture the decrease in beef production (64 percent of soilage) was not of the same magnitude as the decrease in forage consumption per acre compared to the steers fed soilage.

Summary

Two experiments were conducted with beef steers in a study of methods used in the utilization of alfalfa; namely, 5 to 7-day rotational grazing, 1-day rotational grazing, strip grazing, haying and soiling. In one experiment, forage consumption was measured through the use of fecal collections and forage digestibility determined from the chromogen concentration in the feces. Average daily gain for the steers fed green forage in the form of pasture and soilage was the same, while there was a significant decrease in daily gain when the animals were fed alfalfa in the form of hay. In one experiment, the amounts of beef produced per acre expressed as percentages of that produced by the soilage was 77, 79, and 85 for 7-day rotational grazing, 1-day rotational grazing, and haying, respectively, while in the other experiment these were 64, 68, and 79 for 5-day rotational grazing, strip grazing, and haying, respectively. The amount of forage consumed by the steers on pasture was considerably less than that consumed by the steers fed soilage but was of a much higher nutritive value because of selective grazing. Dry matter consumption by the steers fed hay was greater than that of the steers fed soilage and pasture.

Literature Cited

Hardison, W. A., J. T. Reid, C. M. Martin and P. G. Woolfolk. 1954. Degree of herbage selection by grazing cattle. Jour. Dairy Sci. 37:81.

Holmes, W., R. Waite, D. L. Fergusson and D. S. MacLusky. 1952. Studies in grazing management. Jour. Agr. Sci. 42:304.

Ittner, N. R., G. P. Lofgreen and J. H. Meyer. 1954. A study of pasturing and soiling alfalfa with beef steers. JOURNAL OF ANIMAL SCIENCE 13:37.

Lancaster, R. J. and M. P. Bortrum. 1954. Measurement of feed intake by grazing cattle and sheep. IV. A source of error in the chromogen technique of estimating the digestibility of fodders. New Zealand Jour. Sci. and Tech. Sec. A. 35:489.

Reid, J. T., P. G. Woolfolk, C. R. Richards, J. K. Loosli, K. L. Turk, J. I. Miller and R. E. Bloser. 1950. A new indicator method for the determination of digestibility and consumption of forages by ruminants. Jour. Dairy Sci. 33:60.

Reid, J. T., P. G. Woolfolk, W. A. Hardison, C. M. Martin, A. L. Brundage and R. W. Kaufmann. 1952. A procedure for measuring the digestibility of pasture forage under grazing conditions. Jour. Nutr. 46:255.

Snedecor, G. W. 1946. Statistical Methods. The Iowa State College Press. Ames, Iowa.

Winchester, C. F. and W. A. Hendricks. 1953. Energy requirement of beef calves for maintenance and growth. U.S.D.A. Tech. Bull. 1071.

USE OF ANTIPYRINE IN NUTRITIONAL AND MEATS STUDIES WITH CATTLE [1]

G. H. WELLINGTON, J. T. REID, L. J. BRATZLER [2] AND J. I. MILLER

Cornell University [3]

RESEARCH workers in nutrition and meats have long recognized the value of determining the body composition of living experimental animals. Reid *et al.* (1955) have described the relationships existing among the major chemical components of the bovine body and have shown how these relationships can be applied to nutritional investigations. In research studies with cattle it has been usually necessary to slaughter the experimental animal in order to determine accurately the degree of fatness. Recently several indirect methods of measuring the body composition of living animals have been reported. One of the most promising methods is that of Soberman and associates (1949) by which the total amount of water in the body may be determined through the use of antipyrine as an indicator. The method is based upon the principle of determining the degree of dilution of a known quantity of antipyrine injected intravenously. Antipyrine is slowly metabolized and rapidly reaches equilibrium with all tissue water (Soberman, 1949). Since the relationship between body water and fat has been well established (Reid *et al.*, 1955), the amount of body fat can be computed from the percentage of body water.

Brodie *et al.* (1949) described methods for determining the concentration of antipyrine in biological materials. Kraybill *et al.* (1951) applied the antipyrine method as outlined by Soberman *et al.* (1949) to the measurement of body water in 30 cattle. To check his values, Kraybill *et al.* (1951) also calculated body water from carcass specific gravity observations. He found good agreement between the calculated body water content determined by the use of the two indirect methods. In a following publication, Kraybill (1952) gave additional information concerning the application of the specific gravity technique in studies with cattle. The correlation coefficient between the specific gravities of the carcass and the whole animal body was 0.99.

[1] From a portion of a thesis presented by G. H. Wellington to the School of Graduate Studies, Michigan State University, in partial fulfillment of the requirements for the Ph.D. degree, 1954.

[2] Professor of Animal Husbandry, Michigan State University, East Lansing.

[3] Ithaca, N. Y.

The object of the studies reported herein was to determine further the validity of the antipyrine technique for use in studies with cattle. Total body water as determined by antipyrine was checked by direct moisture analysis of the entire bovine body. This report also deals with the effect of three widely different levels of nutrition on body composition changes during the first 80 weeks of life.

Experimental Procedure

Design and Selection of Cattle

Twenty-four Holstein cattle were used in the study. They were randomized within three nutritional levels, Low, Medium, and High, when three to five days of age. Their beginning weights were 80 to 100 lb. The feed intakes supplied 60–75, 100, and 140–160 percent of the upper level of total digestible nutrients (TDN) recommended by Morrison (1948) for growing dairy cattle. The ages at the time of antipyrine measurement and slaughter were 16, 48, 64, and 80 weeks. The cattle slaughtered at 16 and 48 weeks were heifers and those at 64 and 80 weeks were bulls. Each replicate consisted of 3 nutritional treatments $\times$ 4 slaughter ages, a total of 12 cattle per replicate. Musgrave (1951), Dunn (1952), and Sorensen (1953) have reported the detailed feeding data for the cattle.

Animals were taken off feed and water 24 hours prior to the injection of antipyrine. The solution injected contained approximately 0.3 gm. of antipyrine per milliliter. From 7 to 14 gm., depending upon the size of the animal, were injected into the jugular vein. Blood was drawn for serum analysis of antipyrine at 2.5, 3.5, 4.5, and 5.5 hours following injection. Just before injection, an initial blood sample was taken for use in the blank determination of antipyrine in the serum. No anticoagulant was used.

The analysis for determining the concentration of antipyrine in serum water was very similar to the precipitation procedure outlined by Brodie *et al.* (1949), but a few alterations were made. The volumes of blood serum, zinc reagent and 0.75 N NaOH were increased to 5 ml. each. Also 0.1 ml. of 2N sulfuric acid and 0.1 ml. of 0.2 percent $NaNO_2$ solution were used instead of one drop of 4N sulfuric acid and two drops of 0.2 percent $NaNO_2$. The serum samples were centrifuged following the precipitation of the protein. After centrifuging the supernatant was filtered through Whatman No. 42 filter paper. Filtering removed traces of a flocculent precipitate which failed to drop during

centrifuging and subsequently interfered with spectrophotometric readings.

The amount of filtrate resulting from these quantities of serum and reagents was found to be sufficient to form two 3 ml. aliquots. These aliquots were measured into separate "reaction" tubes. One aliquot was used as the blank and the other as the unknown. These samples were then transferred to cuvettes just before measuring optical density. Conducting the reaction in this way rather than in the spectrophotometer cuvettes was found to expedite the analysis of large numbers of samples.

The log. concentration of antipyrine was regressed on the time in minutes after injection to derive the theoretical concentration in total body water. This assumes that there was uniform and instantaneous distribution at zero time with none of the drug being metabolized. The milligrams of antipyrine injected divided by the concentration (mg. per 1.) of antipyrine in the serum water gives the number of liters of body water. Body water in liters divided by body weight (kg.) and multiplied by 100 gives the percentage body water.

Slaughter and Sampling of Body Parts for Moisture Analysis

Live weights were taken just prior to slaughter. Any feces excreted between weighing and slaughter were collected and weighed. Urine was not voided during this interval.

The slaughtering scheme followed was essentially the procedure recommended by Deans (1951). The carcasses were washed, but not shrouded, and allowed to age for seven days at temperatures ranging from 34° to 38° F.

The animal bodies were divided into eight analytical groups for the moisture analysis. Group I, carcass meat, was obtained by removing the edible meat from the left side of the carcasses after aging. An attachment was placed on the meat grinder head to direct half of the meat into one tub and half into a second tub. One tub of meat was rejected and the other reground. After four grindings in this manner, the portion remaining in one tub was mixed by hand and a sample taken. The first three grindings were made using a 3/8 inch plate and the final grinding using a 5/32 inch plate. All group samples were placed in pint glass jars with rubber gaskets and frozen until analyzed for moisture. All carcass weight losses between the hot carcass weight and the weight at boning were assumed to be moisture loss and con-

sidered a part of Group I. The meat removed from Group I represented half of the carcass meat and the weights were doubled when total body water content was calculated.

The hard tissues placed in Group II were taken at slaughter and at the time the meat was boned. Any loss in weight between hard tissue removal and grinding was assumed to be moisture and considered a part of Group II. One half of all hard structures such as head bones, tail bones, and carcass bones went into this group and the weights were doubled for the computation of total body water. Group II was ground in a tractor-powered, belt-driven bone grinder and sampled. The largest ground particles were approximately $3 \times 2 \times 8$ mm.

Group III was a miscellaneous analytical group and included all tissues not listed in other groups. This group, composed of soft tissues except for the cartilage rings of the trachae, was chopped immediately after slaughter, or the following morning, in a 15-inch Hobart Silent Cutter. The rapidly rotating knives of this machine chopped the cartilage rings into small pieces and did not separate them from the softer tissues. After chopping, the group was thoroughly mixed by hand, sampled, and the sample frozen.

Group IV was obtained by opening, emptying, and washing the entire digestive tract. After washing, the intestines were cut into 3– to 4–foot lengths and hung over a horizontal board to drain. The stomachs and esophagus were prepared in the same manner. After draining for 30 to 45 minutes the tissues were chopped. This was followed by hand mixing and sampling.

The fat, Group V, consisted of the ruffle and caul fat. Some of the smaller animals on the low-feeding level did not have enough of these fats to make an analytical group, and the limited fat tissue present at these locations was placed in Group III.

All blood voided at slaughter was collected and weighed. Most of it could be caught when the animal was bled. The blood which ran onto the floor during slaughter was continually recovered by using a rubber floor scraper and shovel. The total weight of Group VI represented that of all blood collected during the bleeding and dressing operations. The blood sample for Group VI analysis was collected during the first seconds of bleeding.

Group VII, the hide and hair, was removed in the usual manner and weighed. The hide was then spread out flesh side up and marked along the dorsal midline. Parallel strips, one-inch wide, were then removed by cutting from this midline, until the edge of the hide was reached.

In this manner a strip was removed from the neck, shoulder, rib, loin, and rump areas of the hide. In addition, a one-inch hide strip was removed from the forehead and cheek and a like strip from the hide of the tail. All strips were then chopped, mixed by hand, and sampled. The larger hide pieces after chopping were approximately 2.5 mm. sq.

Group VIII was made up of all soft tissues which could be removed

TABLE 1. SLAUGHTER WEIGHTS AND DRESSING PERCENTAGES

		Feeding level					
		Low		Medium		High	
Animal number	Age in weeks	Slaughter weight	Hot dressing percent	Slaughter weight	Hot dressing percent	Slaughter weight	Hot dressing percent
202	16	129.8	47.18				
227	16	141.9	46.86				
203	16			179.8	52.42		
226	16			210.6	52.11		
201	16					231.5	56.48
221	16					281.5	49.91
207	48	372.0	47.85				
219	48	353.0	47.31				
209	48			521.0	55.47		
220	48			590.0	54.75		
214	48					756.0	59.52
230	48					664.0	58.28
50	64	607.0	52.39				
61	64	576.0	53.65				
54	64			827.5	53.90		
58	64			727.3	53.21		
52	64					997.0	60.98
72	64					1070.3	59.80
47	80	626.0	55.11				
71	80	652.0	48.61[a]				
53	80			929.0	57.91		
62	80			983.0	55.84		
43	80					1151.0	63.01
60	80					1186.0	62.98

[a] Bull got access to feed during the 24-hour fast.

from the bones of the left half of the head except the tongue and brain. The group was chopped, mixed by hand, and sampled.

After frozen storage each group sample was analyzed for moisture by the toluene distillation method proposed by Bidwell and Sterling (1925). This method was chosen because rather large samples may be easily analyzed. For each determination enough material to yield from 21 to 24 ml. of water was placed under toluene, distilled, and the volume of distilled water measured. Usually samples weighing 25 to 40 gm. could be used for each moisture analysis. These relatively large

samples compensated for the rather coarse tissue particles in some groups.

Total body water was calculated from body group weights and moisture analysis.

Results and Discussion

Body Weights and Carcass Yields

The slaughter weights and dressing percentages classified according

TABLE 2. TOTAL BODY WATER OF CATTLE EXPRESSED AS PERCENTAGE OF LIVE WEIGHT

Animal identity and method of determination	Feeding level					
	Low		Normal		High	
16-week-old heifers						
Animal No.	202	227	203	226	201	221
Water, %						
Tissue analysis	78.31	72.96	69.74	69.75	67.30	71.63
Antipyrine	75.49	69.42	69.54	68.67	67.89	72.15
48-week-old heifers						
Animal No.	207	219	209	220	214	230
Water, %						
Tissue analysis	69.87	67.26	70.55	68.23	58.66	56.28
Antipyrine	72.37	67.03	67.75	70.02	60.73	55.65
64-week-old bulls						
Animal No.	50	61	54	58	52	72
Water, %						
Tissue analysis	71.44	72.63	72.41	70.04	61.94	64.73
Antipyrine	(a)	73.39	(a)	(a)	(a)	66.21
80-week-old bulls						
Animal No.	47	71	53	62	43	60
Water, %						
Tissue analysis	71.73	71.52	69.16	71.53	61.77	56.41
Antipyrine	71.86	74.05	72.29	68.16	60.79	55.54

[a] Not injected due to delayed receipt of antipyrine from the supplier.

to levels of nutrition are shown in table 1. The live weights were correlated with the TDN intake. Live weights likewise increased with advancing age. The cattle on the higher feeding levels were visually fatter and had higher dressing percentages. When analyzed statistically the increases in dressing percentage associated with feeding levels were significant at the one percent level. Differences in dressing percentage due to age were not statistically significant.

TABLE 3. PERCENT OF BODY WATER IN CATTLE AS MEASURED BY ANTIPYRINE AND ANALYSIS OF BODY TISSUES

Method	Range	Mean	Standard deviation
Antipyrine	55.54–74.05	68.00	5.56
Tissue analysis	56.28–78.31	67.95	5.62

Water and Fat Content of the Whole Body

Twenty-four cattle ranging from 16 to 80 weeks of age were analyzed for total body water by determining the amount of moisture in all body tissues. Determinations for total body water by means of antipyrine could not be made on four bulls prior to slaughter due to a delay in delivery of the drug from the supplier.

Table 2 gives the percentage of body water for the individual animals as determined by the antipyrine method and by moisture analysis of the body tissues. Twenty cattle of varying degrees of fatness were analyzed for body water content by both the antipyrine technique and by tissue moisture analysis. The agreement between the antipyrine method and the direct analysis of the tissues is shown in table 3 and figure 1.

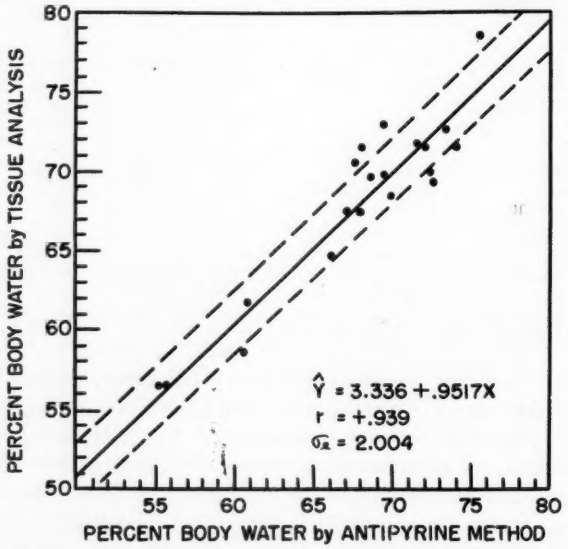


Figure 1. Correlation between two methods of determining body water.

The average difference in the water content measured by the two methods was 0.48 percent. With ten cattle the antipyrine method gave higher estimates of body water than that found by tissue analysis and, with ten, the antipyrine method gave lower percentages. The correlation coefficient between the water contents measured by the two methods was 0.939 with 95 percent confidence limits of 0.850 and 0.976. The agreement between the antipyrine method of determination of body water and determination by tissue analysis was similar to the agreement reported by Kraybill *et al.* (1952) between the antipyrine method and the calculation of body water from the carcass specific gravity.

TABLE 4. TOTAL BODY FAT OF CATTLE EXPRESSED AS PERCENTAGE OF LIVE WEIGHT

	Feeding level					
	Low		Normal		High	
16-week-old heifers						
Animal No.	202	227	203	226	201	221
Percent fat	1.97	6.99	6.89	7.66	8.37	4.65
48-week-old heifers						
Animal No.	207	219	209	220	214	230
Percent fat	4.46	9.17	8.50	6.46	15.54	21.43
64-week-old bulls						
Animal No.	61					72
Percent fat	3.63					9.95
80-week-old bulls						
Animal No.	47	71	53	62	43	60
Percent fat	4.89	3.10	4.64	8.12	15.47	21.57

During the course of these studies and others, it was observed that an occasional measurement of body water by use of the antipyrine method was appreciably erroneous. Although it seems possible that a number of factors could cause error, it was felt that the main one encountered in the application of this procedure is the failure to deliver completely the intended dosage of antipyrine into the jugular blood. In following studies, subsequent body water measurements made on the same animals at intervals of 4 to 6 days appeared to be reasonable estimates and agreed well among themselves. In the first attempts to use the method in this laboratory, poor repeatability of analyses conducted on the same filtrate was experienced. This was traced to a variable concentration of a light precipitate not readily detected visually in filtrates prepared by centrifugation. Centrifugation followed by filtration through paper remedied the condition.

The percentages of total body fat are given in table 4. These were calculated from the corresponding percentages of body water as determined by antipyrine. The equation of Reid *et al.* (1955), $Y = 388.44 + 0.5366X - 227.37 \log X$, in which X is the percentage of body water, was used to calculate the percentage of fat. Reid's equation was calculated from body composition data for cattle found in the literature and included 117 dairy cattle ranging from new-born calves to aged cows. The cattle in this experiment on the higher levels of nutrition had higher fat percentages than those on lower levels. Likewise, the cattle on higher levels were noticeably fatter in appearance before and after slaughter.

Summary

Holstein cattle were fed on low, medium, and high levels of TDN from the first week of age until slaughter at 16, 48, 64, and 80 weeks. The younger two slaughter groups were composed of heifers, the older two groups consisted of bulls.

The percentage of total body water was calculated for 20 cattle by the antipyrine technique and also by analyzing all body tissues for moisture. The correlation coefficient of the comparison of the two methods was 0.939. These results indicate that the antipyrine technique can be used in nutritional and meats investigations for accurately estimating the total body water of cattle *in vivo*. The percentage of total body fat was calculated from the percentage of body water and was correlated with the intake of feed.

Cattle consuming the higher levels of TDN had a higher dressing percentage. Age of cattle showed no significant influence on dressing percentage.

Literature Cited

Bidwell, G. L. and W. F. Sterling. 1925. Preliminary notes on the direct determination of moisture. Ind. and Eng. Chem. 17:147.

Brodie, B. B., J. Axelrod, R. Soberman and B. B. Levy. 1949. The estimation of antipyrine in biological materials. Jour. Biol. Chem. 179:25.

Deans, R. J. 1951. A recommended procedure for slaughtering experimental cattle. Proc. Reciprocal Meat Conf. 4:81. National Live Stock and Meat Board, Chicago, Ill.

Dunn, H. O. 1952. Further studies of the influence of three levels of nutrient intake on the growth and sexual development of young Holstein bulls. Ph.D. thesis, Cornell Univ., Ithaca, N. Y.

Kraybill, H. F., O. G. Hankins and H. L. Bitter. 1951. Body composition of cattle. I. Estimation of body fat from measurement *in vivo* of body water by use of antipyrine. Jour. Appl. Physiol. 3:681.

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. Jour. Appl. Physiol. 4:575.

Morrison, F. B. 1948. Feeds and Feeding. 21st ed. Morrison Publishing Company, Ithaca, N. Y.

Musgrave, S. D. 1951. The influence of three levels of nutrient intake on the growth and sexual development of young Holstein bulls. Ph.D. thesis, Cornell Univ., Ithaca, N. Y.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. Jour. Dairy Sci. In press.

Soberman, R., B. B. Brodie, B. B. Levy, J. Axelrod, V. Hollander and J. M. Steele. 1949. The use of antipyrine in the measurement of total body water in man. Jour. Biol. Chem. 179:31.

Sorensen, A. M., Jr. 1953. The growth and sexual development of young Holstein heifers as influenced by three levels of nutrition. Ph.D. thesis, Cornell Univ., Ithaca, N. Y.

THE USE OF SPECIFIC GRAVITY OF CERTAIN UNTRIMMED PORK CUTS AS A MEASURE OF CARCASS VALUE [1]

A. M. Pearson, L. J. Bratzler, R. J. Deans, J. F. Price, J. A. Hoefer, E. P. Reineke and R. W. Luecke [2]

Michigan Agricultural Experiment Station [3]

HOG carcasses are extremely difficult to evaluate because of the low relationship between the commonly taken measurements and actual carcass leanness. Usually, it has been accepted that average backfat thickness is the simplest measure that is indicative of carcass leanness or fatness. However, Brown *et al.* (1951) reported that specific gravity of the entire carcass was more highly associated with carcass fatness than average backfat thickness. A subsequent study by Whiteman and co-workers (1953) verified the higher correlation for specific gravity than for backfat thickness in relation to several measures of carcass leanness.

Determination of specific gravity of the half-carcass requires a large tank and is a rather cumbersome method that cannot be readily adapted to routine use. This suggests the desirability of using a single untrimmed cut as an index of the entire carcass. Whiteman *et al.* (1953) reported that the specific gravity of the untrimmed ham was highly correlated with the specific gravity of the side from which it was taken. Furthermore, they found that the major chemical components of the ham, namely, water, protein, and ether extract, were highly correlated with specific gravity. Thus, this study was undertaken to ascertain the suitability of specific gravity of three untrimmed cuts as measures of carcass leanness.

Materials and Methods

Experimental Animals

A total of 103 hog carcasses were used in this study. All pigs came from the Animal Husbandry farm and were raised under varying

[1] Journal Article 1815 Michigan Agricultural Experiment Station, East Lansing.

[2] Departments of Animal Husbandry, Physiology and Pharmacology, and Agricultural Chemistry cooperating.

[3] Acknowledgment is made to Dr. W. T. Magee, Dr. R. H. Nelson, and Dr. Amos Kennedy for their suggestions in setting up and interpreting the statistical analysis.

regimes—some coming from feeding experiments while others were raised under the regular farm conditions. However, no attempt was made to segregate the groups according to dietary treatment. These carcasses included 35 Hampshires, 18 Durocs, 20 Chester Whites, 18 Berkshires and 8 crossbreds representing several different breed crosses.

The pigs were removed from feed about 28–29 hours before slaughter but were allowed free access to water. Weights were taken immediately after removal from feed and again prior to slaughter. Backfat thickness was determined at three locations by the live probe as described by Hazel and Kline (1952). All animals were slaughtered in the meats laboratory and the carcasses were chilled for approximately 48 hours before determining specific gravity and cutting the carcass.

Specific Gravity Determinations

Specific gravity was determined by the water displacement method as described by Brown *et al.* (1951). A hog scalding tank was used for underwater weighing. Since the tub was shallow, it was necessary to cut off the feet and weigh them separately; however, the weight was added back to the underwater carcass weight. In addition to determining specific gravity of each side of the carcass, thereby getting a value for the entire carcass, specific gravity was determined for the untrimmed ham, the rough loin and the untrimmed shoulder from each side. If the untrimmed cuts floated, which was not unusual for the rough loin, weights were added to submerge the cut and corrections were made for the additional weight.

Carcass Cutting and Measurement Procedure

The carcass was cut according to the procedure outlined by Cole (1951), except that the ham was removed between the third and fourth sacral vertebrae. All carcass measurements were taken according to the procedure suggested by Strong (1951). Planimeter readings on the area of the *Longissimus dorsi* muscle were made on tracings taken from the right side of the carcass at both the tenth and last rib. After determination of specific gravity of the untrimmed cuts, all cuts were trimmed and weighed to the nearest 0.1 lb. The ham and shoulder were skimmed and all cuts were closely trimmed to remove excess fat. Calculations were made for percentage of lean cuts and primal cuts on both the live and carcass basis, while calculations for both lean and fat trimmings were on the carcass basis only.

Results and Discussion

The untrimmed cuts from the left side were used in making all correlations for a single cut. The close agreement shown in table 1 between the specific gravity for a single cut as compared to the mean value, when the corresponding cut from the other side of the carcass was included, indicated the reliability of the single cut measurement. Furthermore, practically identical standard deviations (table 1) for a single ham, loin, or shoulder as compared to the corresponding value for both cuts pointed to the close relationship existing between corresponding cuts from the opposite side of the carcass.

TABLE 1. MEANS, RANGES AND STANDARD DEVIATIONS FOR VARIOUS MEASUREMENTS

Items	Symbol	Mean	Standard deviation	Range
Live weight—feedlot (lb.)	...	212.3	12.84	176.0 –243.0
Live weight—shrunk (lb.)	...	203.8	12.54	170.5 –234.0
Live probe (in.)[a]	LP	1.69	0.19	1.30 – 2.10
Length carcass (in.)[b]	Len	29.08	1.01	27.00 – 31.57
Length leg (in.)[c]	Leg	20.5	0.64	18.9 – 22.3
Dressing percent[d]	DP	74.99	1.54	71.47 – 78.44
Backfat thickness (in.)[e]	BF	1.77	0.194	1.30 – 2.32
Specific gravity—entire carcass	Sgc	1.032	0.007	1.019– 1.049
Specific gravity—both hams	Sgbh	1.046	0.007	1.032– 1.065
Specific gravity—both loins	Sgbl	1.024	0.008	1.008– 1.040
Specific gravity—both shoulders	Sgbs	1.040	0.006	1.024– 1.056
Specific gravity—left ham	Sglh	1.046	0.007	1.031– 1.065
Specific gravity—left loin	Sgll	1.023	0.007	1.007– 1.040
Specific gravity—left shoulder	Sgls	1.039	0.006	1.022– 1.059
Area *L. dorsi* at 10th rib (sq. in.)[f]	A10	4.00	0.536	2.76 – 5.23
Area *L. dorsi* at last rib (sq. in.)[f]	A1	4.51	0.707	3.05 – 5.92
Lean cuts—live basis (%)[g]	LCL	36.27	1.70	31.96 – 40.65
Lean cuts—carcass basis (%)[h]	LCC	48.34	2.40	43.07 – 52.49
Primal cuts—live basis (%)[g]	PCL	48.20	1.81	43.07 – 52.39
Primal cuts—carcass basis (%)[h]	PCC	64.30	2.35	58.08 – 68.85
Fat trimmings (%)[i]	FT	26.54	2.67	20.65 – 32.55
Lean trimmings (%)[h]	LT	2.64	0.653	1.58 – 4.52
Lean cuts minus fat trim (%)[j]	LCC-FT	21.80	4.76	8.58 – 33.55

[a] Average of 3 probes as follows: just behind shoulder, middle of back and middle of loin.
[b] Length from anterior edge 1st rib to anterior edge of aitchbone.
[c] Length of hind leg from anterior edge of aitchbone to hoof head.
[d] Dressing percentage $= \frac{\text{Cold Carcass Wt. (leaf fat out—head off)}}{\text{Shrunk Live Wt.}} \times 100.$
[e] Average of 4 measurements taken opposite the following sites: 1st rib, 7th rib, last rib and last lumbar vertebra.
[f] Area of *Longissimus dorsi* muscle.
[g] Live basis—on shrunk wt.
[h] Carcass basis—cold wt.
[i] Fat trimmings includes all fat trimmings plus leaf fat.
[j] Lean cuts (cold carcass basis) minus fat trimmings.

Correlations between specific gravity of paired cuts and specific gravity of the entire carcass were highly significant, being +0.94 for the hams, +0.96 for the loins, and +0.92 for the shoulders. Corresponding "r" values for untrimmed individual cuts from the left side were +0.93 for the ham, +0.91 for the loin, and +0.87 for the shoulder. Correlations for that of a single cut and the entire carcass were all high, but slightly reduced as compared to that for paired cuts. The reduction in correlation was greater for the loin than for the other cuts. It is believed that the reduction in association of a single specific gravity measurement of the rough loin is related to weighing errors due to the shape of the cut and the resultant greater buoyancy of the cut in water. The additional determination of specific gravity of the paired cuts would likely tend to reduce the average errors of weighing in water.

The high degree of association between the specific gravity of a single untrimmed ham, shoulder, or loin with that of the entire carcass indicates that any one of these untrimmed cuts can be used as indicative of specific gravity for the entire carcass. Though the differences are small, the ease of underwater weighing of the ham as compared to the loin and the consistently higher correlations as compared to that of the shoulder would indicate a slight preference for the ham. This supports the conclusion of other workers (Brown *et al.*, 1951;Whiteman *et al.*, 1953) that the specific gravity of the ham is closely related to that of the entire carcass.

The correlations between specific gravity for entire carcass, for untrimmed cuts from the left side and for paired untrimmed cuts in relation to other carcass measurements are shown in table 2. All correlations were significant with the exception of three, namely, lean trimmings in relation to carcass specific gravity, carcass specific gravity with dressing percentage, and length of carcass in relation to length of leg. The highest correlation for the various carcass measures of leanness was found to exist between carcass specific gravity and percent lean cuts minus percent fat trimmings with a "r" value of +0.73. Both lean cuts and primal cuts, when expressed as percent of either live weight or carcass weight, were all highly associated with specific gravity for the entire carcass. Percent fat trimmings showed a negative but highly significant relationship ($r = -0.64$) to specific gravity of the carcass.

In examining the correlations between specific gravity of the single untrimmed ham in relation to various other carcass attributes, it is

Results and Discussion

The untrimmed cuts from the left side were used in making all correlations for a single cut. The close agreement shown in table 1 between the specific gravity for a single cut as compared to the mean value, when the corresponding cut from the other side of the carcass was included, indicated the reliability of the single cut measurement. Furthermore, practically identical standard deviations (table 1) for a single ham, loin, or shoulder as compared to the corresponding value for both cuts pointed to the close relationship existing between corresponding cuts from the opposite side of the carcass.

TABLE 1. MEANS, RANGES AND STANDARD DEVIATIONS FOR VARIOUS MEASUREMENTS

Items	Symbol	Mean	Standard deviation	Range
Live weight—feedlot (lb.)	...	212.3	12.84	176.0 –243.0
Live weight—shrunk (lb.)	...	203.8	12.54	170.5 –234.0
Live probe (in.)[a]	LP	1.69	0.19	1.30 – 2.10
Length carcass (in.)[b]	Len	29.08	1.01	27.00 – 31.57
Length leg (in.)[c]	Leg	20.5	0.64	18.9 – 22.3
Dressing percent[d]	DP	74.99	1.54	71.47 – 78.44
Backfat thickness (in.)[e]	BF	1.77	0.194	1.30 – 2.32
Specific gravity—entire carcass	Sgc	1.032	0.007	1.019– 1.049
Specific gravity—both hams	Sgbh	1.046	0.007	1.032– 1.065
Specific gravity—both loins	Sgbl	1.024	0.008	1.008– 1.040
Specific gravity—both shoulders	Sgbs	1.040	0.006	1.024– 1.056
Specific gravity—left ham	Sglh	1.046	0.007	1.031– 1.065
Specific gravity—left loin	Sgll	1.023	0.007	1.007– 1.040
Specific gravity—left shoulder	Sgls	1.039	0.006	1.022– 1.059
Area *L. dorsi* at 10th rib (sq. in.)[f]	A10	4.00	0.536	2.76 – 5.23
Area *L. dorsi* at last rib (sq. in.)[f]	A1	4.51	0.707	3.05 – 5.92
Lean cuts—live basis (%)[g]	LCL	36.27	1.70	31.96 – 40.65
Lean cuts—carcass basis (%)[h]	LCC	48.34	2.40	43.07 – 52.49
Primal cuts—live basis (%)[g]	PCL	48.20	1.81	43.07 – 52.39
Primal cuts—carcass basis (%)[h]	PCC	64.30	2.35	58.08 – 68.85
Fat trimmings (%)[i]	FT	26.54	2.67	20.65 – 32.55
Lean trimmings (%)[h]	LT	2.64	0.653	1.58 – 4.52
Lean cuts minus fat trim (%)[j]	LCC-FT	21.80	4.76	8.58 – 33.55

[a] Average of 3 probes as follows: just behind shoulder, middle of back and middle of loin.
[b] Length from anterior edge 1st rib to anterior edge of aitchbone.
[c] Length of hind leg from anterior edge of aitchbone to hoof head.
[d] Dressing percentage $= \frac{\text{Cold Carcass Wt. (leaf fat out—head off)}}{\text{Shrunk Live Wt.}} \times 100.$
[e] Average of 4 measurements taken opposite the following sites: 1st rib, 7th rib, last rib and last lumbar vertebra.
[f] Area of *Longissimus dorsi* muscle.
[g] Live basis—on shrunk wt.
[h] Carcass basis—cold wt.
[i] Fat trimmings includes all fat trimmings plus leaf fat.
[j] Lean cuts (cold carcass basis) minus fat trimmings.

Correlations between specific gravity of paired cuts and specific gravity of the entire carcass were highly significant, being +0.94 for the hams, +0.96 for the loins, and +0.92 for the shoulders. Corresponding "r" values for untrimmed individual cuts from the left side were +0.93 for the ham, +0.91 for the loin, and +0.87 for the shoulder. Correlations for that of a single cut and the entire carcass were all high, but slightly reduced as compared to that for paired cuts. The reduction in correlation was greater for the loin than for the other cuts. It is believed that the reduction in association of a single specific gravity measurement of the rough loin is related to weighing errors due to the shape of the cut and the resultant greater buoyancy of the cut in water. The additional determination of specific gravity of the paired cuts would likely tend to reduce the average errors of weighing in water.

The high degree of association between the specific gravity of a single untrimmed ham, shoulder, or loin with that of the entire carcass indicates that any one of these untrimmed cuts can be used as indicative of specific gravity for the entire carcass. Though the differences are small, the ease of underwater weighing of the ham as compared to the loin and the consistently higher correlations as compared to that of the shoulder would indicate a slight preference for the ham. This supports the conclusion of other workers (Brown *et al.*, 1951; Whiteman *et al.*, 1953) that the specific gravity of the ham is closely related to that of the entire carcass.

The correlations between specific gravity for entire carcass, for untrimmed cuts from the left side and for paired untrimmed cuts in relation to other carcass measurements are shown in table 2. All correlations were significant with the exception of three, namely, lean trimmings in relation to carcass specific gravity, carcass specific gravity with dressing percentage, and length of carcass in relation to length of leg. The highest correlation for the various carcass measures of leanness was found to exist between carcass specific gravity and percent lean cuts minus percent fat trimmings with a "r" value of +0.73. Both lean cuts and primal cuts, when expressed as percent of either live weight or carcass weight, were all highly associated with specific gravity for the entire carcass. Percent fat trimmings showed a negative but highly significant relationship ($r = -0.64$) to specific gravity of the carcass.

In examining the correlations between specific gravity of the single untrimmed ham in relation to various other carcass attributes, it is

interesting to note that the "r" values tend to be only slightly lower than those for the entire carcass. Correlations follow the same trend except for the much lower relationship between the specific gravity of the left ham and the primal cuts on a carcass basis. The value for specific gravity of a single ham was only +0.37 compared to +0.69 for the specific gravity of the entire carcass in relation to primal cuts on the carcass basis. Analysis of the data by classifying the pigs into 10-lb. weight groups and calculating correlations by weights for specific gravity and primal cuts on the carcass basis revealed no con-

TABLE 2. CORRELATION COEFFICIENTS FOR VARIOUS CARCASS MEASUREMENTS AND SPECIFIC GRAVITY [a]

Item	Sgc	Sglh	Sgll	Sgls	BF	Len	A10
Sgc	....	+0.93	+0.91	+0.87	−0.40	+0.39	+0.53
LC-FT	+0.73	+0.69	+0.66	+0.64	....		
BF	−0.40	−0.34	−0.38	−0.34	....		
Len	+0.39	+0.42	+0.36	+0.40	....		
LCL	+0.71	+0.70	+0.68	+0.57	−0.33	+0.24	
LCC	+0.72	+0.69	+0.65	+0.64	−0.49	+0.28	
PCL	+0.64	+0.63	+0.39	+0.54	−0.15	+0.32	
PCC	+0.69	+0.37	+0.35	+0.33	−0.36	+0.38	
FT	−0.64	−0.63	−0.58	−0.57	+0.51	....	
LP	−0.56	−0.53	−0.63	−0.52	+0.65	....	
Leg	+0.20					+0.12	
A1	+0.55						+0.79
DP	−0.08						
Sgbh	+0.94						
Sgbl	+0.96						
Sgbs	+0.92						
LT	−0.13						

[a] For key to symbols, refer to table 1.

sistent trend by weights, although extreme values ranged from +0.54 for 191–200 lb. pigs to a −0.53 for those weighing 231 lb. and over.

The relatively close relationship between the specific gravity of the left ham with all other measures as compared to the specific gravity of entire carcass and the same measures would indicate that the untrimmed ham is a fairly reliable indicator of carcass leanness. However, the specific gravity of either the rough loin or untrimmed shoulder was not as closely related to measures of carcass leanness as was specific gravity of the ham.

Examination of table 3 shows that as the live weight of pigs was increased by 10-lb. increments, the correlation between backfat thickness and percent lean cuts on a live basis showed a progressive de-

crease. There also appeared to be a similar trend in correlation between backfat thickness and specific gravity of the left ham, but the trend was not consistent. This would indicate that backfat thickness was a better measure of carcass leanness for lighter weight hogs than for heavier carcasses.

Correlation between specific gravity of the left ham and carcass length (table 3) showed a definite trend to decrease as the weight of the hogs increased, ranging from +0.83 for those weighing 190 lb. and under to —0.69 for those weighing over 230 lb. This would indicate that the longer hogs tended to be leaner at lighter weights, while at heavier weights, carcass length was not so closely associated with degree of leanness. Examination of table 3 shows that length was a

TABLE 3. CORRELATIONS BY WEIGHT GROUPS[a]

Weight	Number in group	BF/LCL	BF/Sglh	Sglh/Len
190 lb. and under	4	—0.84	—0.99	+0.83
191–200 lb.	16	—0.44	—0.23	+0.76
201–210 lb.	26	—0.48	—0.43	+0.36
211–220 lb.	34	—0.14	—0.11	+0.48
221–230 lb.	14	—0.13	—0.18	+0.27
231 lb. up	9	+0.04	+0.35	—0.69

[a] Refer to Table 1 for key to symbols.

fairly good measure of leanness up to 200 lb. live weight, but beyond 200 lb. the fatter hogs could not be segregated on the basis of length alone.

Correlations were calculated for the specific gravity of the entire carcass and for specific gravity of the single ham on the various measures of leanness by weight groups. However, except for those measures included in table 3, there were no consistent trends by weights. Similarly, correlations were calculated by sexes. There were no consistent differences in degree of association of leanness by sex. However, in considering average values, the gilts were consistently leaner though the differences in all cases were slight.

The correlation between the specific gravity of the carcass and the area of the *Longissimus dorsi* muscle was +0.55 and +0.53 at the last and 10th rib, respectively. However, the correlation coefficient was +0.79 between the area of the *Longissimus dorsi* muscle at the 10th and last rib. The loin area averaged 0.51 sq. in. greater at the last rib than at the 10th rib which is slightly higher than the value of 0.43

sq. in. reported by Kline and Hazel (1955). Thus a close relationship between the area of this muscle at the two locations was found to exist, though the area at the 10th rib was somewhat smaller.

Summary

In determining the suitability of specific gravity of three untrimmed cuts, i.e., the ham, loin, and shoulder, as measures of carcass leanness, it was found that the specific gravity of each of the cuts was closely associated with specific gravity of the entire carcass. The correlation coefficients were +0.94, +0.96, +0.92 for the ham, loin, and shoulder, respectively, when both cuts from the same carcass were used. However, on a single cut, corresponding values were +0.93, +0.91, and +0.87.

The somewhat higher correlations for specific gravity of a single ham to other measures of carcass leanness indicated that the untrimmed ham was a more reliable index of the entire carcass than either a single rough loin or untrimmed shoulder. With the exception of the relationship between specific gravity of the single ham and percent primal cuts on a carcass basis, the correlations for specific gravity of a single ham closely paralleled those for specific gravity of the entire carcass in relation to other carcass measures. Specific gravity of either the entire carcass or a single ham proved to be superior to backfat thickness as a measure of carcass leanness.

In examination of correlation coefficients by weight groups, indications were obtained that both backfat thickness and length of carcass were better measures of leanness for lighter weight pigs.

Literature Cited

Brown, C. J., J. C. Hillier and J. A. Whatley. 1951. Specific gravity as a measure of the fat content of the pork carcass. JOURNAL OF ANIMAL SCIENCE 10:97.

Cole, J. W. 1951. Slaughtering, chilling, and cutting methods for pork carcass evaluation. Proc. Fourth Ann. Reciprocal Meat Conf. 4:111.

Hazel, L. N. and E. A. Kline. 1952. Mechanical measurement of fatness and carcass value on live hogs. JOURNAL OF ANIMAL SCIENCE 11:313.

Kline, E. A. and L. N. Hazel. 1955. Loin area at tenth and last rib as related to leanness of pork carcasses. JOURNAL OF ANIMAL SCIENCE 14:659.

Strong, C. L. 1951. Standard methods of measuring and grading for pork carcass evaluation. Proc. Fourth Ann. Reciprocal Meat Conf. 4:108.

Whiteman, J. V., J. A. Whatley and J. C. Hillier. 1953. A further investigation of specific gravity as a measure of pork carcass value. JOURNAL OF ANIMAL SCIENCE 12:859.

SLAUGHTER AND CARCASS CHARACTERISTICS OF SHORTFED YEARLING, HEREFORD, AND BRAHMAN X HEREFORD STEERS

O. D. Butler, B. L. Warwick and T. C. Cartwright [1]

Texas Agricultural Experiment Station [2]

THE Texas Agricultural Experiment Station, at its substation No. 23, is engaged in a long range cattle breeding program with the objective of increasing the efficiency of beef production. Gain testing, progeny testing, and heat tolerance studies are being conducted using several breeds and their crosses, as described by Warwick *et al.* (1954). Initial plans for the studies included collection of slaughter and carcass information as well as cooking and palatability data to complete the rating of cattle with measured live performance.

The foundation herd included high grade Hereford and Brahman cows. The Herefords were selected at random and bred to gain tested bulls, where available, of several breeds. Initial emphasis was placed on Hereford and Brahman bulls, and the results reported in this paper include data for four years from a random sample of the progeny of these bulls bred to Hereford cows.

Procedure

Cows and calves were maintained under uniform management until the calves were weaned and placed on feed. A short period of adjustment was allowed, followed by a standard feeding test of 140 days. The self-fed ration included cottonseed meal, ground sorghum grain, ground hegari fodder, ground johnsongrass hay, and either ground alfalfa leaf meal or vitamin A concentrate or both. The steers were divided into two groups, one receiving 66 to 68 percent concentrates, and the other 30 to 35 percent concentrates. The influence of ration will be reported in a later paper, but is eliminated from these results as equal numbers of each breed were included from each ration.

The steers were slaughtered within two weeks of the end of the test period. Delivery was made to the Meats Laboratory on the

[1] Assistance of J. K. Riggs, J. G. Moffitt, G. T. King, R. L. Simms, R. L. Reddish, J. C. Miller, H. O. Hill, and R. E. Patterson and the statistical laboratory staff is acknowledged.

[2] College Station.

campus the afternoon before slaughter. A trucking distance of a little more than 100 miles resulted in approximately 3 percent shrinkage. The steers were then held overnight with no feed, but with water available. Detailed shrinkage information will be reported later in a paper accounting for some of the factors influencing dressing percentage.

TABLE 1. SLAUGHTER AND CARCASS CHARACTERISTICS OF SHORT-FED YEARLING HEREFORD AND BRAHMAN × HEREFORD STEERS [a]

Item	Mean values		Probability of chance occurrence
	Hereford	Brahman × Hereford	
Number of steers	59	90	
Slaughter live weight, lb.	743.5	782.2	.001
Chilled carcass weight, lb.	445.7	490.1	.001
Dressing percentage, chilled	59.9	62.6	.001
Area of eye muscle, unadjusted, sq. in.	8.45	9.00	.05
Carcass grade	High good +	High good −	N.S.
Percent hindquarter	49.7	50.2	.01
Percent forequarter	50.3	49.8	.01
Percent rib	8.9	8.9	N.S.
Percent short plate	6.8	6.9	.05
Percent foreshank	4.4	4.2	.001
Percent brisket	4.9	4.8	N.S.
Percent chuck	25.2	24.9	.01
Percent flank	5.6	5.7	N.S.
Percent full loin, trimmed	16.1	15.6	.01
Percent round, rump on	24.7	25.1	N.S.
Percent cushion round	15.4	15.5	.1
Percent high priced cuts (Loin+rib+round, rump on)	48.8	49.9	N.S.
Estimated percent lean in carcass	58.3	58.6	.05
Estimated percent fat in carcass	27.5	26.1	N.S.
Estimated percent bone in carcass	15.4	15.4	N.S.

[a] Summary of data for 1951, 1952, 1953, and 1954.

Rather detailed slaughter and carcass information was recorded patterned after the recommendations of Deans (1951) and Naumann (1951). Estimations of lean, fat, and bone, and standard cutting tests were made according to Hankins and Howe (1946).

Results and Discussion

The most important data are summarized in table 1. Production figures favored the crossbred steers. Much of this advantage was realized before weaning. Herefords made gains equal to or greater

than the crossbreds in the feedlot. A definite and marked advantage in dressing percentage was shown quite consistently by the crossbreds. This finding is in agreement with the earlier observations of Black *et al.* (1934).

Carcass measurements confirmed the observed difference in length of leg and length of body, with Herefords averaging about 3 cm. shorter in body, and 6 cm. shorter in length of leg after adjustment to equal carcass weight. The crossbreds showed greater depth of chest measured at the seventh thoracic vertebra, but no significant differences in adjusted width of rounds or shoulders were found.

The area of eye muscle, unadjusted, was greater for the crossbred steers, but this difference became insignificant when adjusted to an equal carcass weight basis. Actually the Herefords showed 1.9 sq. in. per cwt. of carcass compared to 1.8 for the crossbreds.

Herefords graded slightly higher, but coding and application of statistical tests showed that the difference was not consistent enough for statistical significance.

The percentage yields of wholesale cuts were surprisingly alike. Several differences were consistent enough for statistical significance, but none was of great economic significance.

Estimated percentages of lean, fat, and bone obtained from physical separation of the standard 9–10–11 rib cut showed great similarity.

General agreement with the findings of Carroll *et al.* (1955) will be observed on comparison of results.

These cutting results reflect doubt on the importance of compactness, a standard characteristic sought for desirable conformation, and included in official specifications for grades of carcass beef. If the yield of high priced cuts including loin, rib, and round (rump on) is taken as a measure of desirable conformation, no significant difference was found in this study. The "comprest" type Hereford steers of Stonaker *et al.* (1952) yielded 50.7 percent of the high priced cuts mentioned, and the figure for the "conventional" type steers was identical. Willey *et al.* (1951) found comprest Hereford steers to have 49.6 percent high priced cuts, while "regular" steers had 49.5 percent. The lower figures of Willey *et al.* (1951), and of the steers in this study compared to those of Stonaker *et al.* (1952) is probably due to removal of the entire kidney knob from the loins instead of the conventional method of leaving some fat.

These data indicate that there is a strong tendency toward proportional development of bone and muscling among steers of about the

same age. Fat is the greatest variable, and may have a marked influence on cutting yields of very fat cattle as observed by Callow (1948).

Summary

Fifty-nine Hereford and 90 Brahman X Hereford steers from Hereford dams raised under the same management, and self-fed in drylot on uniform rations, were slaughtered and compared. The crossbred steers weighed about 40 lb. more at slaughter, and about 55 lb. more in carcass. Crossbreds showed the greatest advantage during the suckling period.

Dressing percentage was decidedly in favor of the crossbred steers, as they yielded 62.6 percent compared to 59.9 percent for the Herefords.

There was little difference in carcass grade as determined by an official U.S.D.A. grader, or in yields of wholesale cuts, although the crossbred carcasses were longer bodied and longer of leg. Results reflect considerable doubt on the importance of compactness as a conformation factor in beef steers.

Literature Cited

Black, W. H., A. T. Semple and J. L. Lush. 1934. Beef production and quality as influenced by crossing Brahman with Hereford and Shorthorn cattle. U.S.D.A. Tech. Bul. 417.

Callow, E. H. 1948. Comparative studies of meat. II. The changes in the carcass during growth and fattening, and their relation to the chemical composition of the fatty and muscular tissue. Jour. Agr. Sci. 38:174.

Carroll, F. D., W. C. Rollins and N. R. Ittner. 1955. Brahman-Hereford crossbreds and Herefords—gains, carcass yields, and carcass differences. JOURNAL OF ANIMAL SCIENCE 14:218.

Deans, R. J. 1951. A recommended procedure for slaughtering experimental cattle. Proc. Fourth Annual Reciprocal Meat Conf., National Livestock and Meat Board, 81.

Hankins, O. G. and Paul E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. U.S.D.A. Tech. Bul. 926.

Naumann, H. D. 1951. A recommended procedure for measuring and grading beef for carcass evaluation. Proc. Fourth Annual Reciprocal Meat Conf., National Livestock and Meat Board, 89.

Stonaker, H. H., M. H. Hazaleus and S. S. Wheeler. 1952. Feedlot and carcass characteristics of individually fed comprest and conventional type Hereford steers. JOURNAL OF ANIMAL SCIENCE 11:17.

Warwick, Bruce L., T. C. Cartwright and M. W. Hazen. 1954. Beef cattle performance at Bluebonnet Farm. Texas Agr. Exp. Sta. Bul. 790.

Willey, N. B., O. D. Butler, J. K. Riggs, J. H. Jones and P. J. Lyerly. The influence of type on feedlot performance and killing qualities of Hereford steers. JOURNAL OF ANIMAL SCIENCE 10:195.

EXTENSIBILITY OF SINGLE BEEF MUSCLE FIBERS [1, 2]

HSI WANG, D. M. DOTY, F. J. BEARD,[3] J. C. PIERCE [4] AND O. G. HANKINS [5]

American Meat Institute Foundation
The University of Chicago

SINCE meat is composed of a number of tissue elements, it is reasonable to assume that its organoleptic characteristics are determined jointly by the physical and chemical characteristics of each of the components as well as their relative proportions and distribution. Muscle variability in these respects seems to account for the wide range in tenderness and other organoleptic qualities of various meat cuts (Ramsbottom and Strandine, 1948).

When considering factors associated with tenderness (Brady, 1937; Hammond, 1940) the muscle fibers as a histological entity seemed not to have received as much attention as that directed to the roles played by the connective tissues: collagen (Beard, 1924; Bell *et al.*, 1941; Cover, 1937 and 1941; Lehmann, 1907; Mackintosh *et al.*, 1936; Mitchell *et al.*, 1926 and 1928); elastin (Mackintosh *et al.*, 1936; Mitchell *et al.*, 1928; Winegarden *et al.*, 1952), and fat (Beard, 1924, 1942; Hankins and Ellis, 1939). Yet the importance of muscle fibers to any consideration of tenderness is obvious. In the first place, they constitute more than three-quarters of the entire volume in muscle tissue. Secondly, tenderness is in reality a sensation, which may be measured by the "chewing" force needed to cut through the meat during mastication. Undoubtedly, the muscle fibers are related in some way to this chewing force required.

The above considerations led us to measure the extensibility of single muscle fibers isolated from two muscles from five groups of carcasses in both the raw and cooked state. Our main objectives in this endeavor were: (a) to determine whether or not the extensibility of muscle fibers may be related to carcass grade and weight differences; (b) to see how

[1] Journal Paper No. 114, American Meat Institute Foundation. This work was conducted at the American Meat Institute Foundation, and was supported in part by Research and Marketing Funds under contract with the U.S.D.A.

[2] The authors wish to acknowledge the technical assistance of James Wachter, Donald Fredrickson, Virginia Bates and Evalyn Granquist for shear force determinations and preparation of samples and to express their appreciation to Eugenia Hoffert and Irene Dabkiewicz Ginger for obtaining the taste panel scores for tenderness included in this paper.

[3, 4, 5] U. S. Department of Agriculture.

it is affected by aging and cooking; and (c) to ascertain if it bears any relationship to tenderness of the meat. The results of these studies are presented here with the hope that they may stimulate similar studies and further analysis of the role of muscle fibers and/or other muscle constituents as to their influence on meat palatability.

Materials and Methods

Forty-four *Longissimus dorsi* and thirteen *Semitendinosus* samples fresh or aged (2–4 weeks) from 3 U. S. lightweight prime steers, 3 U. S. heavyweight prime steers, 3 U. S. lightweight good steers, 3 U. S. heavyweight good steers and 3 U. S. commercial grade cow carcasses were used in this study. Samples of both muscles used for measurement of muscle fiber extensibility were taken from one side of the carcasses; corresponding samples from the other side were cooked (broiled) in the manner described previously (Wang *et al.*, 1954).

Muscle fibers were obtained by cutting $2 \times 3 \times 0.5$ cm. pieces of cooked meat in a Waring blendor at a speed of 10,000 RPM for two or three seconds. In order to yield undamaged muscle fibers up to 15 mm. in length, the blades of the blendor cutter were dulled by filing. For blending raw meat, resistance equivalent to approximately 50 ohms, was inserted serially in the circuit to reduce the speed of the blendor to 3,300 RPM, and the time period used was five seconds.

The macerated tissue consisted of tiny fragments of connective tissues and small bundles of muscle fibers and single fibers. Only single muscle fibers completely free from any association with endomysial tissues were used for the muscle fiber extensibility determinations. Muscle fibers of this description and considerably longer than 5 mm. were transferred to a petri dish containing water which was placed on the glass stage of a binocular dissecting microscope. A transparent plastic ruler was placed beneath the petri dish. Using a No. 1 objective (1x) and a pair of 9x eyepieces (approximately 2.5x total magnification) individual muscle fibers were focused above the ruler. With two pairs of steel watchmaker's forceps having fine, ground tips each fiber was firmly gripped at two points leaving exactly 5 mm. between the points. While the muscle fiber was held between two forceps in this manner, one of the two forceps was moved to stretch the fiber from the other forceps which remained stationary. The 5 mm. long fiber thus was slowly extended until it broke, and the length of the stretched fiber at the breaking point was noted. The length in millimeters in addition to

the original 5 mm. was recorded as the "extensibility" index in each case, and twenty such readings were made for each sample.

The muscle fibers were randomly picked but all were about average diameter. The ones used for this determination were free from any injury which might have been incurred during blendoring. Certain precautions were taken to insure against measuring the extensibility from imperfect fibers. First, only those instances in which the breaks occurred at least 1 mm. from either end were counted. Occasionally, a few fibers from a sample broke instantly after force was applied. Since these breaks might be due to mechanical injury not detectable at the magnification used, such readings were discarded also. However, when most fibers from a sample broke instantly upon pulling, a zero index was recorded for it. The average of the 20 readings for each sample was taken as the index of each sample.

Shear strength of each raw and cooked sample was measured with the Warner-Bratzler shear apparatus, using one-half inch diameter cylinders at a temperature of 45° F. Also all cooked samples were submitted to a trained taste panel of six members for tenderness evaluation. The samples were scored on a 1 to 10 scale (the more tender the sample the higher the rating).

Results and Discussion

Complete data of muscle fiber extensibility expressed as millimeters over the initial length of the fiber (5 mm.) together with shear force and tenderness rating are presented in table 1.

Carcass Grade and Carcass Weight Influences

The data indicate a trend for greater extensibility of muscle fibers from the lower grade carcasses within each carcass weight class. This trend manifested itself in the following: the muscle fiber extensibility of *Longissimus dorsi* muscle was greatest for commercial cow, and decreased for heavy good and heavy prime carcasses in this order.

Within the same grade, extensibility was higher in the muscles from the heavy carcasses. In this respect, the commercial cows apparently aligned itself with the heavy good steer carcasses. This carcass weight influence is believed to reflect the animal's age. The failure to register any extensibility at all in the muscles from the light prime and light good carcasses probably was another expression of age influence.

TABLE 1. EXTENSIBILITY OF 5 mm.-LONG INDIVIDUAL MUSCLE FIBERS, SHEAR STRENGTH AND TENDERNESS SCORE FOR TISSUE FROM DIFFERENT CARCASS GRADES AFTER DIFFERENT AGING PERIODS
(as arithmetic averages with standard deviations)

Carcass grade and weight	Muscle	Aged	No. samples	Raw		Cooked		Tenderness score (1–10)
				Fiber extensibility	Shear	Fiber extensibility	Shear	
		Weeks		mm.	lb.	mm.	lb.	
Light prime	Longissimus dorsi	0	6	0	4.7 ± 1.7	0.5 ± 0.1	9.3 ± 1.1	6.8 ± 1.2
		2	3	0	5.5 ± 1.5	4.6 ± 1.6	7.6 ± 1.4	7.8 ± 0.9
	Semitendinosus	0	1		16.7	0	10.9	4.7
		2	1	4.5	12.9	2.3	7.9	8.0
Heavy prime	Longissimus dorsi	0	6	1.1 ± 0.4	4.6 ± 1.2	4.0 ± 0.8	6.4 ± 0.4	7.5 ± 0.8
		2	3	2.1 ± 0.5	3.3 ± 1.3	4.0 ± 0.5	5.5 ± 0.8	8.5 ± 0.8
		4	1	1.3	1.8	4.1	5.5	9.0
	Semitendinosus	0	1	3.3	15.0	4.2	10.4	5.0
		2	1	2.5	11.3	3.17	7.4	5.7
		4	1	1.5	17.9	2.8	10.2	8.0
Light good	Longissimus dorsi	0	5	0	5.3 ± 1.7	6.6 ± 0.4	13.2 ± 2.5	5.1 ± 0.5
		2	2	0	7.4 ± 1.7	4.2 ± 0.3	9.0 ± 0.1	7.8 ± 0.1
	Semitendinosus	0	1	0.8	12.4	4.9	12.0	4.5
		2	1	0	10.4	2.3	8.6	6.8
Heavy good	Longissimus dorsi	0	5	1.2 ± 0.3	4.8 ± 0.5	7.5 ± 0.1	7.7 ± 2.4	6.4 ± 1.3
		2	2	0	4.3 ± 0.5	3.2 ± 0.2	7.9 ± 1.6	7.4 ± 1.2
		4	2	0	5.6 ± 1.2	2.7 ± 0.6	6.9 ± 1.4	8.7 ± 0.7
	Semitendinosus	0	1	0	15.7	7.0	10.0	4.5
		2	1	0	11.5	2.6	8.5	5.8
		4	1	0	16.0	1.8	9.2	7.2
Commercial cow	Longissimus dorsi	0	5	1.9 ± 0.2	7.7 ± 2.3	6.4 ± 0.7	13.3 ± 1.3	4.1 ± 0.7
		2	2	0	5.0 ± 0.9	3.8 ± 0.4	9.7 ± 0.8	7.0 ± 0.7
		4	2	0	3.6 ± 0.6	4.0 ± 0.6	9.6 ± 1.3	7.0 ± 0.3
	Semitendinosus	0	1	1.5	1.6	6.6	15.8	3.4
		2	1	0	10.6	2.3	9.6	5.7
		4	1	0	16.5	2.0	13.4	7.0

Muscle Differential

The two muscles studied revealed no marked differences in muscle fiber extensibility in the fresh raw state but the two muscles were affected differently in extensibility of their fibers as a result of aging or cooking as indicated below.

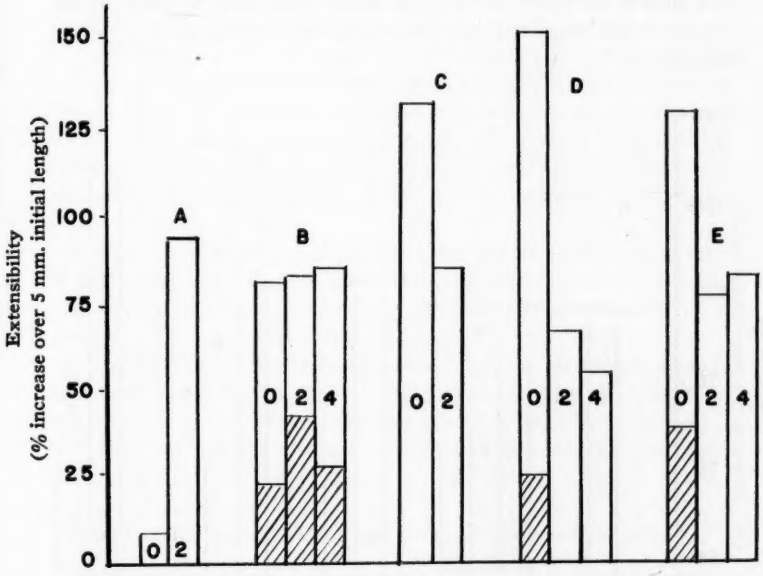


Figure. 1. Average extensibility of single muscle fibers of *Longissimus dorsi* from five groups of carcasses: *A*, U. S. lightweight prime steer; *B*, U. S. heavyweight prime steer; *C*, U. S. lightweight good steer; *D*, U. S. heavyweight good steer; *E*, U. S. commercial cow. Shaded bars represent raw weat; open bars, cooked samples after 0, 2, and 4 weeks aging as indicated.

Effect of Aging

The general effect of aging was to decrease the extensibility of fibers in both muscles. This effect is well brought out by the decreasing bar lengths representing the aged samples (figures 1 and 2) within each carcass group. The samples that best showed this aging effect came from the *Semitendinosus* muscles of the heavy prime carcasses (figure 2). Note that this change in both the raw and cooked conditions was,

by and large, more pronounced in the *Semitendinosus* than in the *Longissimus dorsi* muscle. It would appear, therefore, that the process of aging decreased the muscle fiber extensibility to a greater degree in the former than in the latter muscle (Moran and Smith, 1929; Steiner, 1939).

Generally, aging influenced the extensibility from heavy carcasses more than it did that from light carcasses. There was no great further increase in the degree of this aging effect beyond the 14 day period, however.

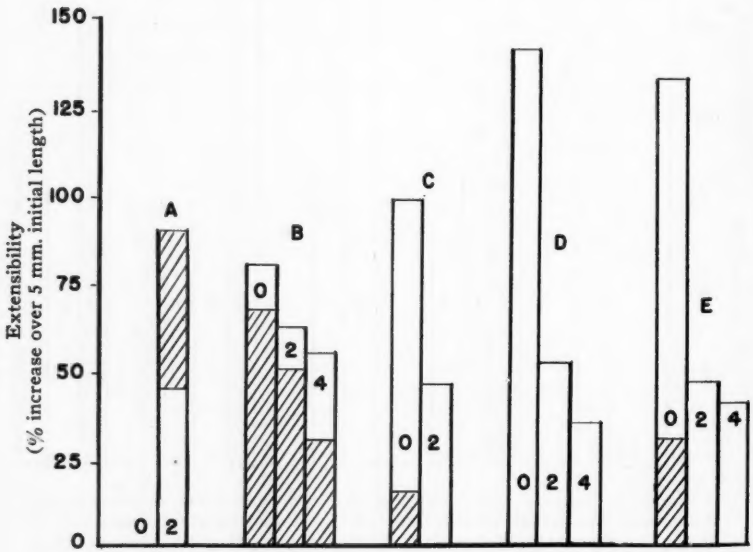


Figure 2. Average extensibility of single muscle fibers of *Semitendinosus* from five groups of carcasses: *A*, U. S. lightweight prime steer; *B*, U. S. heavyweight prime steer; *C*, U. S. lightweight good steer; *D*, U. S. heavyweight good steer; *E*, U. S. commercial cow. Shaded bars represent raw meat; open bars, cooked samples after 0, 2, and 4 weeks aging as indicated.

Effect of Cooking

It was demonstrated quite conclusively that cooking makes muscle fibers more extensible (figures 1 and 2). Our results thus confirm a number of previous studies (Ramsbottom *et al*, 1945; Ramsbottom and Strandine, 1948; Satorious and Child, 1938), which show the coagu-

lating and toughening effect of heat on muscle fibers. Furthermore, cooking showed a different effect on the two muscles: it increased the fiber extensibility of the *Semitendinosus* muscles to a lesser degree than it did that of the *Longissimus dorsi* muscles.

Carcass grade and carcass weight, too, seemed to have an influence on the degree of the effect of cooking. Generally, cooking increased the extensibility to a lesser degree in samples from the higher grades. Thus, for both muscles, the fibers from the prime samples increased in extensibility to a lesser degree than corresponding samples from the U. S. good carcasses upon cooking. Also, cooking increased the extensibility of the muscle fibers of the *Semitendinosus* to a greater degree in samples from the heavy carcasses than it did in those from the light carcasses; this was not generally true for the *Longissimus dorsi* samples. The effect of carcass weight appeared more pronounced in the higher grade carcasses.

Finally, the effect of cooking as just described was noticeably lessened or nullified in aged samples, especially those from the lower grade carcasses. This was particularly true of the *Semitendinosus* muscle (compare carcass groups D and E in figures 1 and 2).

It might be noted with passing interest that the mechanism whereby aging and cooking had such opposite effect on the extensibility of muscle fibers is not known. The two processes must be recognized as two forms of protein changes occurring under completely different conditions.

Shear Strength, Muscle Fiber Extensibility and Tenderness

When considering any characteristic of a meat component from a practical standpoint, the relationship, if any, to some organoleptic property should be determined. Consequently the possible relation of muscle fiber extensibility to the most important organoleptic property, namely tenderness, was considered.

Many investigations (Beard, 1924; Lehmann, 1907; Mackintosh *et al.*, 1936; Mitchell *et al.*, 1928; Paul, 1943; Ramsbottom *et al.*, 1945; Satorious and Child, 1938) have indicated the inverse relationship between collagen content and meat tenderness, and other studies (Mackintosh, *et al.*, 1936; Mitchel *et al.*, 1928) have pointed out the fact that elastin probably plays a minor role in this respect, although more recent work (Hiner *et al.*, 1955) has indicated both collageneous and elastic fibers to be important factors influencing tenderness. The tenderizing effect of intramuscular fat has been proposed (Beard, 1924; 1942)

but not entirely proved (Hankins and Ellis, 1939; and Mitchell *et al.*, 1928). The dispersion of fat in cooked meat (Wang *et al.*, 1954) may be of great importance from a tenderness standpoint. The influence of muscle fiber diameter and muscle bundle size on meat tenderness has been suggested (Brady, 1937; Moran and Smith, 1929; Hiner *et al.*, 1953) but the investigators hold somewhat contradictory views.

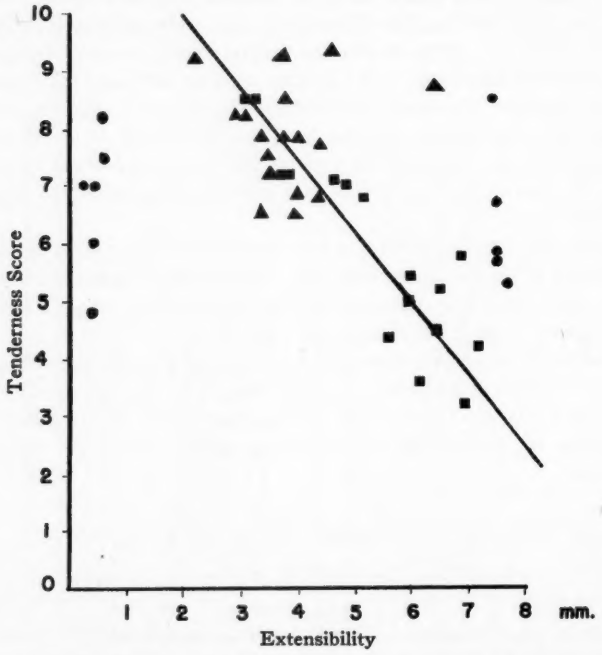


Figure 3. Relationship between tenderness and muscle fiber extensibility in 44 cooked *Longissimus dorsi* samples from 15 carcasses.

▲ = aged samples
● = fresh lightweight prime and heavyweight good steer samples
■ = fresh heavyweight prime, lightweight good steer and commercial cow samples

The data obtained on the two muscles, *Longissimus dorsi* and *Semitendinosus,* in this investigation suggest that there is an inverse relationship between fiber extensibility and tenderness of cooked meat (figures 3 and 4). The relationship was not general in that samples from two

groups of carcasses, lightweight prime and heavy good, failed to fall along the regression lines.

As a further check on the possible relationship between muscle fiber extensibility and tenderness, linear correlation coefficients were calculated for tenderness scores and muscle fiber extensibility and for shear force and muscle fiber extensibility. The validity of some of the

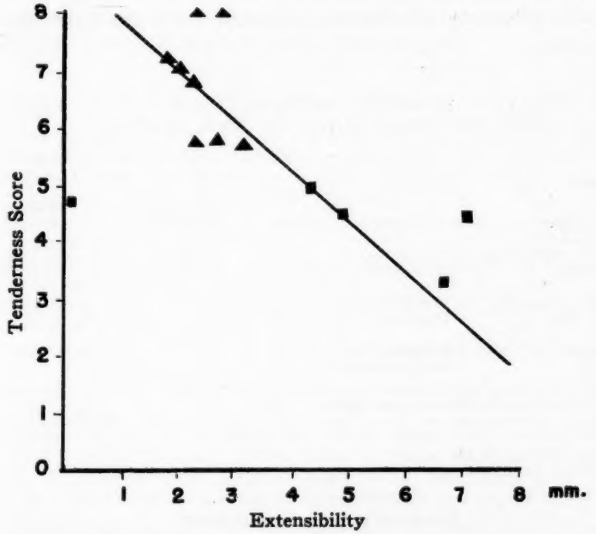


Figure 4. Relationship between tenderness and muscle fiber extensibility in 13 cooked *Semitendinosus* samples from 15 carcasses.

■ = fresh
▲ = aged

coefficients and their significance is of course questionable in some cases because of the limited number of samples studied, particularly for the *Semitendinosus*. The results of these calculations (table 2) show that there was undoubtedly some relationship between fiber extensibility and tenderness but that in some groups of carcasses (lightweight prime steers and heavy good steers) other unknown factors must play a very important role. Shear force of the cooked meat generally correlates well with tenderness scores; muscle fiber extensibility and shear force were also shown to correlate to about the same degree as fiber extensibility and tenderness scores.

The value of the present work lies principally in opening a new approach to problems of meat palatability by investigating properties of a single constituent of muscle tissue. Such an approach would be more direct and basic than conventional ones because the existing tests, including the shear and taste panel evaluation cannot be freed from the criticism that what they actually measure is an over-all characteristic of the meat. Only by measuring properties of individual constituents can we hope to obtain basic data needed to understand and evaluate the various meat qualities.

TABLE 2. RELATION OF MUSCLE FIBER EXTENSIBILITY TO TENDERNESS AND SHEAR FORCE OF COOK SAMPLES

		All samples [a]		Selected samples [b]	
Correlation	Muscle	No.	Correlation coefficient	No.	Correlation coefficient
Muscle fiber extensibility vs. tenderness	Longissimus d.	44	—0.43**	26	—0.85**
	Semitendinosus	13	—0.65*	8	—0.86**
Muscle fiber extensibility vs. shear force	Longissimus d.	44	0.36*	26	0.82**
	Semitendinosus	13	0.45	8	0.61
Shear force vs. tenderness	Longissimus d.	44	—0.80**	..	....
	Semitendinosus	13	—0.51	..	....

[a] Fresh and aged samples from all carcass groups.
[b] Fresh and aged samples from heavy prime steer, light good steer and commercial cow carcasses.
* Significant at 5 percent level.
** Significant at 1 percent level.

Summary and Conclusion

Forty-four *Longissimus dorsi* and thirteen *Semitendinosus* (fresh and aged) from five different carcass groups were studied. Both raw and cooked slices of these samples were cut up in a specially modified Waring blendor to isolate single undamaged muscle fibers for determination of their extensibility. The latter was expressed in mm. over 5 mm. initial length of a single fiber stretched to its breaking point. Tenderness scores and shear strength on each of the cooked samples were also obtained.

The data show the specific effect of aging and cooking on muscle fiber extensibility. The former process decreased extensibility while the latter considerably increased it. An analysis of the data revealed that there existed a fair correlation (negative) between muscle fiber extensibility and tenderness of these samples and between muscle fiber extensibility and shear force (positive) for samples from three of the carcass groups studied.

The muscles did not show appreciable differences in the extensibility of the raw fibers, but they were affected to a significantly different degree by aging and cooking. Other influences due apparently to carcass grade, and carcass weight, or age of the animal were also shown.

Correlations between muscle fiber extensibility, between shear force and muscle fiber extensibility in both the raw and cooked conditions, and between shear force and tenderness were presented from which a relationship between muscle fiber extensibility and tenderness of the meat was indicated, but not generally established.

Literature Cited

Beard, F. J. 1924. A study of tough and tender beef. Unpub. MS. Thesis, Library, Iowa State College, Ames, Iowa.

Beard, F. J. 1942. The influence of sex upon the quality of beef. Unpub. Ph.D. Thesis, Library, Iowa State College, Ames, Iowa.

Bell, E. F., A. F. Morgan and A. Dorman. 1941. Collagen determination in cooked meat. Food Research 6:245.

Brady, D. E. 1937. A study of the factors influencing tenderness and texture of beef. Amer. Soc. Anim. Prod. Proc. 30:246.

Cover, Sylvia, 1937. The effect of temperature and time of cooking on tenderness of roasts. Texas Agr. Expt. Sta. Bull. 542.

Cover, Sylvia, 1941. Effect of metal skewers on cooking time and tenderness of beef. Food Research 6:233.

Hammond, J. 1940. Some factors affecting the quality and composition of meat. Chem. & Ind. 59:521.

Hankins, O. G. and N. R. Ellis. 1939. Fat in relation to quantity and quality factors in meat animal carcasses. Amer. Soc. Anim. Prod. Proc. 32:314.

Hiner, R. L., O. G. Hankins, H. S. Sloane, C. R. Fellers and E. E. Anderson. 1953. Fiber diameter in relation to tenderness of beef muscle. Food Research 18:364.

Hiner, R. L., E. E. Anderson and C. R. Fellers. 1955. Amount and character of connective tissue as it relates to tenderness in beef muscle. Food Technology 9:80.

Lehmann, K. B. 1907. Studies über die Zähigkeit das Fleisches und ihre Ursachen. Arch. Hyg. 63:134.

Mackintosh, D. L., J. L. Hall and O. K. Vail. 1936. Some observations pertaining to tenderness of meat. Amer. Soc. Anim. Prod. Proc. 29:285.

Mitchell, H. H., T. S. Hamilton and W. T. Haines. 1928. Some factors affecting the connective tissue content of beef muscle. Jour. Nutr. 1:165.

Mitchell, H. H., R. L. Zimmerman and T. S. Hamilton. 1926. The determination of the amount of connective tissue in meat. Jour. Biol. Chem. 71:379.

Moran, T. and E. C. B. Smith. 1929. Post-mortem changes in animal tissues—the conditioning or ripening of beef. Gt. Brit. Dept. Sci. and Indus. Res., Food Invest. Board Spec. Report No. 36.

Paul, Pauline C. 1943. Changes in the palatability, microscopic appearance and electrical resistance in beef during the onset and passing of rigor and during subsequent storage. Ph.D. Thesis, Iowa State College.

Ramsbottom, J. M., E. J. Strandine and C. H. Koonz. 1945. Comparative tenderness of representative beef muscles. Food research 10:498.

Ramsbottom, J. M. and E. J. Strandine. 1948. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Research 13:315.

Satorious, M. J. and A. M. Child. 1938. Effect of coagulation on press fluid, shear force, muscle cell diameter, and composition of beef muscle. Food Research 3:619.

Steiner, G. 1939. Die postmortalen Veranderungen des Rindermuskels bei verschiedenen Temperaturen, gemessen an seinem mechanischen Verhalten. Arch. Hyg. Bakt. 121:193.

Wang, H., Ellen Rasch and Virginia Bates. 1954. Histological observations on fat loci and distribution in cooked beef. Food Research 19:314.

Wang, H., D. M. Doty, F. J. Beard, J. C. Pierce and O. G. Hankins. 1954. Extensibility of single muscle fibers. JOURNAL OF ANIMAL SCIENCE 13:972.

Winegarden, M. W., Belle Lowe, J. Kastelic, E. A. Kline, A. R. Plagge and P. S. Shearer. 1952. Physical changes of connective tissue of beef during heating. Food Research 17:172.

THE INFLUENCE OF SIZE AND TYPE ON GROWTH AND DEVELOPMENT OF CATTLE [1]

JAMES F. KIDWELL AND JOHN A. MCCORMICK

University of Nevada [2]

THE systematic exploration of the application of population genetics to animal improvement has made available effective and efficient selection techniques and mating systems. However, suitable selection criteria must be developed before these improved breeding plans can be fully exploited by beef cattle breeders. Rate and economy of gain and carcass grade and composition are among the important criteria for slaughter animals.

There is considerable evidence indicating that differences in rate and economy of gain may reflect differences in the composition of the increase, which may be determined by differences in mature size. Guilbert and Gregory (1944) concluded that biased estimates of feed utilization might be obtained when cattle of different mature size were fed on a time constant basis. Knapp and Baker (1944) suggested correcting to a weight constant basis or feeding to a weight constant basis to obviate errors introduced by time constant feeding. Kleiber (1936) concluded that total efficiency of energy utilization is independent of body size. Procter *et al.* (1934) demonstrated that work efficiency is similar in Shetland Ponies and Percherons. Brody and Ragsdale (1935) found that dairy goats, Jersey cattle and Holstein cattle convert food energy into milk energy with similar efficiency. Branaman (1940) found approximately equal TDN requirements per lb. of final feedlot weight of lamb produced by Southdowns and Hampshires. Zeller and Hetzer (1944) noted differences in feed requirements per lb. of gain when small, intermediate and large type Poland China barrows were fed to a constant weight (225 lb), but no differences when fed to a constant degree of fatness. Woodward *et al.* (1942) found that large type Hereford steers gained faster and used less feed per lb. of gain than small type steers when fed for a time constant period. Washburn *et al.* (1948) found that conventional type Shorthorn steers gained faster, yet re-

[1] This work is in cooperation with the Animal and Poultry Husbandry Research Branch, A.R.S., U.S.D.A., under Western Regional Project W-1 on beef cattle breeding research. It was also supported by a grant from the Sears-Roebuck Foundation.

[2] Departments of Animal Husbandry and Newlands Field Station, Reno and Fallon, Nevada, respectively.

quired longer than compact type Shorthorns to reach an equivalent finish. Feed costs per lb. of gain were approximately equal for both types. Willey *et al.* (1951) found that when fed for a time constant period regular type Hereford steers gained more rapidly than comprest steers, but except for a greater percentage of shank from the regular steers, there were no significant differences in economy of gain or carcass characteristics. Stonaker *et al.* (1952) concluded that, when fed to a constant degree of fatness, there was no significant difference between comprest and conventional type Hereford steers with respect to economy of gain, days on feed, slaughter age, percent of the major carcass cuts, and percent of separable bone, muscle and fat in the 9, 10, 11-rib cut. The conventional steers gained more rapidly, reached a higher weight, and had a higher dressing percent than the comprest steers. Knox (1954) reported a decided advantage in lifetime production for large type cows run on semi-arid southwestern range lands.

Since beef cattle are produced under a wide variety of economic and biological conditions, and there is a market requirement for beef produced by many types of cattle, it appears that there may be no single ideal size or type. It may be necessary to develop several types, each adapted to a particular economic and biological situation.

In order to make intelligent choices of selection criteria it is necessary to know the relations between body size, growth rate, economy of gain, and carcass quality and composition for different types and sizes of cattle. The purpose of this investigation was to describe the comparative growth, development, feedlot performance and carcass characteristics of Holstein steers, as representing an extreme in size and type, with "regular" or "conventional" Hereford steers.

Materials and Methods

A total of 35 Hereford and 39 Holstein steers were involved in this study. There were two groups of Herefords, and three of Holsteins. The first group of 28 Herefords was selected for uniform weight and age as weanling calves. They were wintered on native mountain meadow hay, ranged during the summer, run on aftermath for 42 days in the fall, wintered on native meadow hay, ranged the following summer, and full fed for 122 days prior to slaughter. The data included periodic individual weight gains, economy of gain for the group during the feeding period, carcass grade, dressing percent, and percent of five wholesale carcass cuts. The second group of seven Herefords were selected as typical of conventional long yearling Hereford feeder steers

and individually full fed a fattening ration for 140 days prior to slaughter. Data include feeder grade, weight gains, feed consumption, slaughter grade, dressing percent, carcass grade, carcass shrink, percent of five wholesale cuts, percent of physically separable muscle, bone and fat in the 9, 10, 11-rib cut and chemical composition of the fat and muscle.

The first group of Holsteins consisted of 19 calves born during a 10-month interval. They were handled on a standard dairy calf regime, i.e., milk and calf starter with access to hay, during the first 23 weeks. When the youngest of the 12 older calves reached 23 weeks, they were group fed alfalfa hay for 16 weeks. The 6 younger steers were group fed alfalfa during the last six weeks of this period. The 19 steers were pastured as a group for 16 weeks, then rotated between feed lot and pasture at 14-day intervals for 16 weeks and fed alfalfa hay for a period of 126 days, and slaughtered. The data obtained were the same as for the first group of Herefords.

The second Holstein group consisted of 13 steers, handled in a similar manner to the first. Only growth data were obtained from these animals.

The third group of seven Holstein steers were handled in the same manner as the first two until they were approximately 15 months old. They were then individually full fed the same grain ration, but slightly different hay than the second group of Herefords, for the same period, and slaughtered. The same data were obtained.

The data were amenable to analysis of variance and correlation analysis as described by Snedecor (1946).

Results

The first group of 28 Herefords and the first 19 Holsteins constitute the first experiment, and the last group of 7 Herefords and 7 Holsteins the second experiment. The second group of 13 Holsteins contributed only to the data used in constructing the growth curve.

Experiment I

Figure 1 presents the weight-time growth curves and indicates the differences in mature size. The more rapid growth of the Herefords up to 35 weeks can probably be attributed to their nursing as compared to the "calf regime" for the Holsteins. The Hereford curve is subject to fluctuations due to winter feeding and range, while the Holstein

curve represents continuous good hay or pasture. The differences in plane of nutrition preclude direct comparison of the two curves. However, they illustrate the difference in mature size and, to some extent, in growth pattern between the two breeds. At about 120 weeks of age and 1,050 lb., the Hereford curve begins to plateau; the fattening ration during the last 17 weeks was only slightly effective in increasing rate of gain. The Holstein curve continues in a straight line fashion, and at 110 weeks and 1,375 lb. shows no evidence of a plateau. The curves clearly illustrate that comparisons of rate of gain between animals of different mature size are valid only if made over a comparable segment of the growth curve and treatments are alike.

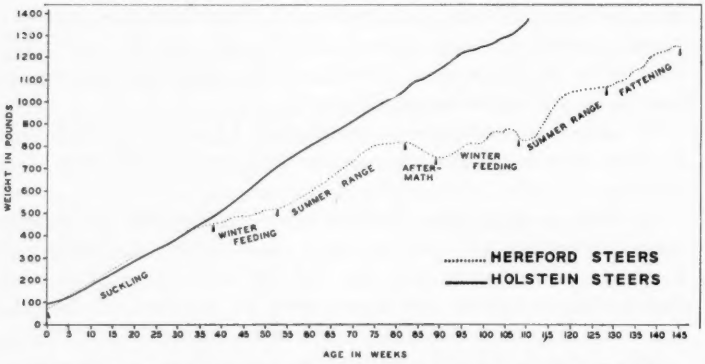


Figure 1. Weight-time growth curve for Herefords and Holsteins.

Economy of gain decreased with increasing weight in the Holsteins. Approximately 6.7 lb. of hay were required per lb. of gain between 325 and 525 lb.; approximately 8 lb. of hay per lb. of gain were required between 525 and 975 lb.; and 18.2 lb. of hay per lb. of gain were required between 975 and 1,175 lb. During the fattening period, which can be compared with the last mentioned Holstein period, the average weight of the Herefords increased from about 1,075 to 1,250 lb. A lb. of gain required 8.3 lb. hay and 5.9 lb. grain concentrate. The difference in economy of gain is likely the result of differences in the composition of the increase.

Carcass grade, dressing percent and cut out values of five wholesale cuts expressed as percent of the entire carcass are shown in table 1. Correlations between carcass grades and live weight, dressing percent,

TABLE 1. CARCASS DATA FROM HEREFORD AND HOLSTEIN STEERS, EXPERIMENT I

Grade	Number of steers	Average live weight	Average carcass weight	Average dressing percent [a]	Percent of carcass				
					Round	Loin	Rib	Chuck	Plate
		lb.	lb.	Herefords					
Prime	1	1177	736	62.3	24.0	23.4	8.8	35.1	8.6
Choice	9	1309	805	61.7	24.3	24.2	9.5	34.4	7.6
Good	15	1224	753	61.9	24.7	23.4	9.6	34.8	7.5
Commercial	3	1114	688	62.1	25.2	22.5	9.4	35.9	7.1
				Holsteins					
Good	1	1360	839	61.7	25.0	24.6	9.3	33.6	7.6
Commercial	11	1147	671	58.5	25.5	22.3	9.0	36.3	6.8
Utility	6	945	536	56.7	26.2	21.5	9.1	37.1	6.0
Cutter	1	840	460	54.8	28.9	19.2	8.7	37.1	5.9

[a] Based on shrunk liveweight and chilled dressed weight.

shrink and percent of five wholesale cuts of both groups are shown in table 2.

These data indicate that within the Holsteins, but not the Herefords, grade is highly associated with weight. This suggests that the degree of fatness was the critical factor in determining carcass grade in the Holsteins, but that in the Herefords, since all were well finished, conformation assumed a more important role.

The data indicate that dressing percent is highly associated with grade in the Holsteins, but not the Herefords. This supports the suggestion that fatness largely determined carcass grade in the Holsteins, but not in the Herefords.

Shrink is not associated with grade in either group. A significant correlation would be expected if fat cover affects shrink.

The percent loin in the carcass is highly associated with grade in both groups. There is no relation between percent rib or chuck and carcass grade in either group. The significant negative correlation between percent round and grade in the Holsteins, and the negative trend in the Herefords is contrary to expectation on the basis of judging

TABLE 2. CORRELATION OF CARCASS GRADE WITH CARCASS TRAITS AND PERCENT OF CARCASS OF FIVE WHOLESALE CUTS, EXPERIMENT I

	Weight	Dressing percent	Percent shrink	Percent of				
				loin	rib	round	chuck	plate
Herefords	0.33	−0.01	0.04	0.73**	−0.26	−0.36	−0.32	0.42
Holsteins	0.80	0.69**	−0.07	0.69**	0.08	−0.69**	−0.45	0.63**

** Significant at 1 percent level.

theory and practice. The positive correlation between carcass grade and percent plate in the Holsteins, and the supporting trend in the Herefords is also unexpected in view of judging theory and practice. The discrepancy might be explained on the assumption that to a certain degree, fatness is important in determining grade; but as fattening progresses, fat is deposited further down the fore rib, increasing the fat on the plate and hence the percent plate.

Differences in percent of five wholesale cuts, live weight, dressing percent and shrink are shown in table 3. The Holsteins have significantly less rib, loin, and plate but more chuck and round than the Herefords. It is possible that these differences are to some extent the result of

TABLE 3. DRESSING PERCENT, PERCENT SHRINK AND FIVE WHOLESALE CUTS EXPRESSED AS PERCENT OF CARCASS FOR HEREFORDS AND HOLSTEINS, EXPERIMENT I

	Live weight	Dressing percent [a]	Shrink [b]	Percent of carcass				
				Loin	Rib	Round	Chuck	Plate
Herefords	1238	62.22	1.57	23.57	9.51	24.61	34.78	7.50
Holsteins	1078	57.86	1.41	22.01	9.06	25.92	36.44	6.56
Difference	160**	4.36**	.16	1.56**	.45**	1.31**	1.66**	.94**

** Significant at 1 percent level.
[a] Based on shrunk live weight and chilled carcass weight.
[b] Expressed as percent of chilled carcass.

differences in degree of fatness. The Holsteins weighed less and had a lower dressing percent than the Herefords, but there was no diffrence in percent shrink.

Experiment II

Differences in feeding and management of the animals in the first experiment preclude critical comparison of rate and economy of gain. The second experiment was designed to permit a direct comparison of growth and development of the two types under similar management when full fed, and at comparable initial weights. Table 4 presents the growth and carcass data. The Hereford steers averaged about twenty months, and the Holsteins about fifteen months at the start of the trial. The data indicate that the Holsteins gained more rapidly, and on less grain per lb. of gain than the Herefords. There was no difference in hay consumption per lb. of gain. In contrast with the first experiment there was no difference in dressing percent. The Holsteins had less shrink than the Herefords, confirming the results of the first experiment. The numerical values indicate carcass grades of top good

and average commercial for the Herefords and Holsteins respectively. The percent of five wholesale cuts was based on the right half only. The data are in close agreement with those of the first experiment.

TABLE 4. GROWTH AND CARCASS DATA, EXPERIMENT II

Item	Herefords	Holsteins
Initial weight	765.0	761.4
Final weight	1,017.9	1,089.6
Av. daily gain, lb.	1.66	2.34**
Hay per lb. gain, lb.	7.03	7.50
Grain per lb. gain, lb.	6.37	3.82**
Dressing percent [a]	59.0	59.5
Carcass grade	82.9	70.0**
Percent shrink [b]	3.51	2.74*
Percent of right half, chilled carcass		
Loin	23.6	21.2*
Round	25.4	26.4
Rib	9.8	9.3*
Chuck	34.2	36.0*
Plate	7.0	7.1
Percent composition of 9, 10, 11 rib		
Bone	14.1	18.2**
Muscle	54.0	59.5**
Fat	31.8	22.4**
Chemical composition of muscle and fat from 9, 10, 11 rib		
Dry matter, percent	52.1	44.3*
Fat, percent	36.6	25.4*
Protein, percent	14.4	16.9**
Ash, percent	0.7	0.8*

* Difference significant at 5 percent level.
** Difference significant at 1 percent level.
[a] Based on shrunk live weight and chilled carcass weight.
[b] Expressed as percent of chilled carcass weight.

Immediately prior to slaughter the following body measurements were taken: height at withers, chest width, hooks width, heart girth, round and length. The Holsteins were about 4.5 inches higher at the withers and 3.3 inches longer than the Herefords. There were no significant differences between the other measurements.

The percent of separable bone, muscle and fat in the 9, 10, 11-rib cut indicates a higher proportion of fat and a lower proportion of bone and muscle in the Herefords. Chemical analysis of the muscle and fat tend to confirm these observations.

Discussion

The purpose of this investigation was to study the influence of mature size and type on growth, development, feedlot performance and carcass characteristics. Holstein steers were used because they provided the most readily available examples of an extremely large mature size.

Although differences in plane of nutrition preclude direct comparison of the weight-time growth curve, the data appear sufficient to conclude that animals of a larger mature size have a longer period of essentially straight line post weaning growth, and a greater rate of increase during this period than animals of a smaller mature size. This clearly indicates that comparisons of "rate of gain" are valid only when made over comparable segments of the growth curve. It would not be valid, for example, to compare rate of gain between 500 and 900 lb. or between 240 and 380 days of age of an animal of 1,500 lb. mature weight with one of 2,200 lb. mature weight.

The data clearly indicate similar conclusions with respect to economy of gain. At equal initial weights animals of greater mature size will increase a greater proportion of bone and muscle and a smaller proportion of fat when full fed for a constant period which does not permit both groups to reach mature weights. This results in a greater economy of gain as measured by lb. of feed per lb. of gain. These data clearly illustrate the gross error in defining lb. of feed per lb. of gain as "efficiency of food utilization" for comparative purposes unless it can be shown that the composition of the increase is identical among the animals compared.

The influence of type and mature size on carcass traits is not nearly so marked as is its influence on growth. At the slaughter weights used in this study, the larger, rangier animals have 1.5 to 2.5 percent less loin, 0.5 percent less rib, 0.1 to 0.9 percent less plate, and 1.0 to 1.3 percent more round, and 1.7 to 1.8 percent more chuck. The differences in round and plate indicated in Experiment I are contrary to expectation on the basis of judging theory and practice. None of the differences are as large as expected on the basis of visual appraisal of the live animals. This is in agreement with the conclusion of Guilbert and Gregory (1952) that small differences in conformation have been over emphasized.

Differences in the percent of physically separable bone, muscle and fat in the 9, 10, 11-rib, and chemical composition of the muscle and fat tend to confirm the influence of size and type on carcass composi-

tion already noted. It is interesting to note that the present human diet calls for less fat and more protein, particularly protein of animal origin.

Fuller (1927, 1929) compared Holsteins, Angus and Angus X Holstein crosses under conditions of full feeding. The results of this study are in close agreement with those of Fuller with respect to rate and economy of gain and carcass quality. More recently Rumery and Baker (1953) reported similar results when Holstein steers were full fed fattening rations from 13 to 20 months of age.

Only limited palatability tests by an untrained panel were made. Seventy-five percent of the panel could identify utility as less tender. There was no distinction between the good and commercial with respect to tenderness, and no distinction among the three grades with respect to flavor. This suggests that beef from young animals of commercial grade is of acceptable flavor and tenderness among most consumers.

Summary and Conclusions

Thirty-five "conventional" Hereford and 39 Holstein steers were used to study the influence of size and type on growth, development, feed lot performance and carcass characteristics of cattle. Since the two types of cattle were of different breeds, the possibility that part of the observed differences were, in fact, breed differences cannot be conclusively eliminated. There is, however, no evidence of any "breed effect," other than size. On the basis of these data, and under the conditions of this study, it appears reasonable to conclude that, at a given weight or age, animals of larger mature size will gain more rapidly on less feed than animals of smaller mature size. Further, carcasses of the larger animals will contain a higher proportion of bone and muscle, and a lower proportion of fat. Differences in percent of the various wholesale cuts are small.

Although these data are not sufficiently extensive to warrant broad generalizations, they suggest important implications in interpreting data from rate and economy of gain tests. They also have significant implications in establishing selection criteria relating to size and type.

Literature Cited

Branaman, G. A. 1940. Some factors in lamb production associated with size and type in mutton sheep. Jour. Agr. Res. 60:473.

Brody, S., and A. C. Ragsdale. 1935. Evaluating the efficiency of dairy cattle. Missouri Agr. Exp. Sta. Bul. 351.

Fuller, J. G. 1927. Fattening cross-bred versus purebred calves for baby beef. Wisc. Bul. 396:32.

Fuller, J. G. 1929. Baby beef from crossbred Angus-Holstein calves. Wisc. Agr. Exp. Sta. Bul. 405:58.

Guilbert, H. R. and P. W. Gregory. 1944. Feed utilization tests with cattle. JOURNAL OF ANIMAL SCIENCE 3:143.

Guilbert, H. R. and P. W. Gregory. 1952. Some features of growth and development of Hereford cattle. JOURNAL OF ANIMAL SCIENCE 11:3.

Kleiber, M. 1936. Problems involved in breeding for efficiency of food utilization. Proc. Amer. Soc. An. Prod. 247.

Knapp, B. Jr. and A. L. Baker. 1944. Correlation between rates and efficiency of gain in steers. JOURNAL OF ANIMAL SCIENCE 3:219.

Knox, J. H. 1954. The effect of type on: Rate and efficiency of gain, early maturity, carcass excellence and cow production. Stockman's Handbook, Wash. State College: 16.

Procter, R. C., S. Brody, M. M. Jones and D. W. Chittenden. 1934. Efficiency of work horses of different sizes and body weights. Missouri Res. Bul. 209.

Rumery, Myron G. and Guy N. Baker. 1953. Growing and Feeding Holstein steers for beef. Nebraska Agricultural Expt. Sta. Bul. 418.

Snedecor, G. W. 1946. Statistical methods. Iowa State College Press, Ames, Iowa, 4th Ed.

Stonaker, H. H., M. H. Hazaleus and S. S. Wheeler. 1952. Feedlot and carcass characteristics of individually fed comprest and conventional type Hereford steers. JOURNAL OF ANIMAL SCIENCE 11:17.

Washburn, L. E., J. Matsushima, H. E. Pearson and R. C. Tom. 1948. Nutrient utilization by compact and conventional type shorthorn steers. JOURNAL OF ANIMAL SCIENCE 7:127.

Willey, N. B., O. D. Butler, J. K. Riggs, J. H. Jones and P. J. Lyerly. 1951. The influence of type on feedlot performance and killing qualities of hereford steers. JOURNAL OF ANIMAL SCIENCE 10:195.

Woodward, R. P., R. T. Clark and J. N. Cummings. 1942. Studies on large and small type hereford cattle. Montana Agr. Exp. Sta. Bul. 401.

Zeller, J. H. and H. O. Hetzer. 1944. Influence of type of hog on production efficiency. U.S.D.A. Circ. 698.

A STUDY OF VAGINAL AND UTERINE PROLAPSE IN HEREFORD CATTLE [1]

R. R. WOODWARD AND J. R. QUESENBERRY [2]

United States Department of Agriculture

PROLAPSE of the vagina and uterus constitutes a serious problem in many herds. Milne (1954) states that there appears to be a higher incidence of prolapse in the western range area than in other sections of the United States. Milne (1954) and Knox (1952) expressed the opinion that prolapse is more common among Herefords than other breeds of beef cattle. The latter observation has been made by a number of practicing veterinarians in the northern plains area.

A variable incidence of prolapse between breeds suggests heritable differences for this characteristic. Possible differences in the occurrence of prolapse between areas or between years in the same herd would indicate that nutrition may have an effect upon the relative incidence or degree of prolapse.

The histories of two experimental herds of Hereford cattle are presented in this study, giving further information as to the causative factors of vaginal and uterine prolapse.

Data and Discussion

The data were collected at the United States Range Livestock Experiment Station at Miles City, Montana, under cooperative projects with the Montana Agricultural Experiment Station during the period 1935–54, inclusive. Supplemental data from the North Montana Branch Station at Havre, Montana, cover the period 1943–54, inclusive.

A complete prolapse of the uterus occurred only while the cervix was relaxed, or from parturition to approximately 72 hours thereafter. Prolapse of the vagina, which may include a portion of the uterus and/or the bladder, occurred both during and following pregnancy but most frequently appeared immediately before or after parturition. As there were no records of vaginal prolapse occurring in dry cows, the percentage incidence of prolapse at the Miles City Station was computed from the total number of births from 1935–54, inclusive. During this

[1] A contribution of Western Regional Project W-1 on Beef Cattle Breeding Research.

[2] The authors wish to express their appreciation to J. J. Urick of the North Montana Branch Station for supplying the data from the Havre herd.

period there was a total of 93 cases of prolapse from 7859 births or an incidence of 1.2 percent. Of the 93 cases there were 71 cases of vaginal prolapse and 22 cases of uterine prolapse. All cows that survived a prolapse were culled within the year.

Loss of the cow resulted in 68 percent of the cases of uterine prolapse and in 18 percent of the cases of vaginal prolapse. Most of the

TABLE 1. INCIDENCE OF PROLAPSE BY YEARS AT MILES CITY

Year	Number of births	Number of cases of prolapse	Percentage incidence
1935	269	0	0.0
1936	245	0	0.0
1937	146	2	1.4
1938	261	4	1.5
1939	220	0	0.0
1940	237	0	0.0
1941	326	1	0.3
1942	366	1	0.3
1943	401	1	0.2
1944	437	0	0.0
1945	438	9	2.1
1946	461	4	0.9
1947	481	8	1.7
1948	522	13	2.5
1949	410	9	2.2
1950	410	11	2.7
1951	555	8	1.4
1952	597	9	1.5
1953	559	6	1.1
1954	518	7	1.4
Total	7859	93	...
Average	...	...	1.2

latter deaths resulted during periods when observation of the cows on the range was made only at weekly intervals. The number of fatalities was determined to a large extent by the adequacy and time of treatment. If a cow could be moved to be treated under relatively sanitary conditions, the prognosis was generally good.

Variation by Years

The number of prolapse cases at the Miles City station is listed by years in table 1. There was an increase in the percentage incidence in 1945 which remained relatively high to date, although the 1951–54 incidence has remained approximately at the 20-year mean. A wide

range in the percentage incidence occurred between years, the highest percentage being recorded in 1950.

Station Effect

The effect of differing environmental conditions upon the relative incidence of prolapse was studied in a comparison of data from the experimental herds at the Miles City and Havre stations. Included were the cows from both herds sired by bulls from Lines 1 and 2 of the Miles City station. Management procedures at the two stations were similar during the period studied, but there were differences in the planes of nutrition provided to the herds. The range at Havre is lush, mountain pasture, a portion of which remains green during the entire grazing season. At Miles City there are ordinarily only 2–3 months in which there is green forage on the short-grass native range.

TABLE 2. INCIDENCE OF PROLAPSE IN FEMALE PROGENY OF SIRES FROM LINES 1 AND 2 AT MILES CITY AND HAVRE

Station	Miles City	Havre
Number of births	3323	837
Number of prolapse cases	58	6
Percentage incidence	1.7	0.7

In the winter the herd at Havre is fed hay approximately five months. The Miles City herd is wintered on the range and fed 1–2 lb. of a protein supplement for about two months prior to the calving season, although hay is fed during the more severe winters. The range at Miles City is predominantly in rough, eroded hills and at Havre is in a foothill and mountain region.

In table 2 is shown the percentage incidence of prolapse that has occurred in the female progeny of sires from Lines 1 and 2 at Miles City and Havre for the period 1943–54, inclusive. The incidence at Miles City proved to be significantly higher ($P<.05$) than at Havre, indicating that plane of nutrition or specific nutritional differences may be predisposing factors to vaginal and uterine prolapse.

Effect of Age of Cow

Another factor considered as a possible determinant of the relative incidence of prolapse was the age of the cow at the time the prolapse occurred. In table 3 data from the Miles City herd are presented. These data represent all births from cows 3–10 years of age, inclusive.

TABLE 3. INCIDENCE OF PROLAPSE BY AGE OF COW AT TIME OF OCCURRENCE AT MILES CITY

Age of cow	3	4	5	6	7	8	9	10
Number of births	1779	1502	1258	1036	802	618	480	312
Number of prolapse cases	28	12	14	8	11	8	6	6
Percentage incidence	1.6	0.8	1.1	0.8	1.4	1.3	1.3	1.9

The percentage incidence between age groups was not significantly different statistically in the Miles City herd, but there was a trend toward a reduced incidence after the first parturition and an increased incidence after cows reached seven years of age.

Variation by Lines and Sires

Throughout the period included in this study a portion of the herd has consisted of cows from closed inbred lines. The incidence of prolapse by lines is listed in table 4.

The percentage incidence of vaginal and uterine prolapse ranged from 0.0 percent in Line 7 to 7.1 percent in Line 11. Differences between lines proved to be statistically significant ($P<.02$). As there was a relatively large number of births in Line 1 compared to the other lines, the incidence in Line 1 (1.7 percent) was tested against the incidence in the balance of the herd (0.9 percent). The ratio of cases to births was found to be significantly higher ($P<.05$) in Line 1 than in the composite of all other lines.

Additional evidence suggesting heritable differences in the occurrence

TABLE 4. INCIDENCE OF PROLAPSE BY LINE OF DAM AND SIRE AT MILES CITY [a]

Line	Number of births	Number of cases of prolapse	Percentage incidence
1	1752	29	1.7
2	445	1	0.2
3	219	1	0.5
4	203	2	1.0
5	262	2	0.8
6	109	3	2.8
7	106	1	0.9
8	71	0	0.0
9	95	1	1.1
10	111	1	0.9
11	42	3	7.1

[a] Does not include grade cows in station herd.

of prolapse was found in an over-all examination of pedigrees, although this portion of the study was limited by the lack of histories of the acquired lines and foundation cows in the station herd. Prairie Domino, a Line 1 sire, appeared in a high percentage of the pedigrees of affected cows. In the 175 births recorded from daughters of Prairie Domino there were 8 cases of prolapse or 4.6 percent of the total. This proved to be a significantly higher incidence ($P<.01$) than was recorded for the balance of the herd during the same period (1943–1953 inclusive). The dam of Prairie Domino appeared in two additional pedigrees tracing through her daughters.

Referring again to table 4 it may be noted that the incidence of prolapse was highest in Line 11. Line 11 was formed by a reciprocal cross of Lines 1 $\times$ 5. In 42 births thus far recorded in the line there were three cases of prolapse. The three cows were all granddaughters or great-granddaughters of Prairie Domino through female descent. They were sired by Young Mischief 561, a Line 5 bull.

Common female ancestors were found in all but two of the pedigrees in which there were known histories. One cow was a common ancestor through female descent in seven pedigrees of predominantly Line 1 breeding. Altogether the preponderance of evidence indicated an heritable factor or factors influencing the occurrence of vaginal and uterine prolapse.

Although prolapse is a serious problem in some herds it appears that the incidence could be reduced by severe culling of the affected cows and their male and female progeny.

Summary

A total of 93 cases of vaginal and uterine prolapse occurred in 7859 births in the range Hereford herd at the United States Range Livestock Experiment Station at Miles City, Montana, during the period 1935–54, inclusive. Yearly variations in the percentage incidence ranged from 0.0 percent to 2.7 percent. The incidence at this station was found to be significantly higher than the incidence at the North Montana Branch Station at Havre, Montana, when births from cows of similar breeding were considered for the same years. The lower plane of nutrition at the Miles City station may have been responsible for the higher incidence of prolapse.

Differences in the occurrence of prolapse were not statistically significant between age groups of cows. There was a tendency for a

higher percentage of cases to occur at the time of the first calving and after the cow reached seven years of age.

Significant line differences in the incidence of prolapse suggest an hereditary susceptibility for this characteristic. It would follow that vaginal and uterine prolapse, generally recognized to be most serious in the Hereford breed, could be controlled to some degree by rigorous culling. Further study of the relationship between the incidence of prolapse and nutritional deficiencies undoubtedly would result in a more complete solution of the problem.

Literature Cited

Knox, J. H. 1952. Breeds of beef cattle for the southwest. Jour. Range Mgt. 5:115.

Milne, E. J. 1954. Efocaine—an aid in the treatment of bovine vaginal prolapse. Jour. Am. Vet. Med. Assn. 124:108.

A GENETIC ANALYSIS OF WEANING WEIGHTS IN A RANGE BEEF HERD OPERATED UNDER OPTIMUM AND SUB-OPTIMUM NUTRITIONAL REGIMES

W. C. ROLLINS AND K. A. WAGNON [1]

University of California [2, 3]

EFFECTIVE breeding plans are based on a knowledge of the composition and relative importance of the genetic and of the environmental variation of a trait in the population under consideration.

If genetically similar material is subjected to markedly different environments a difference in average response is expected. Does such a change in environment also effect a change in the composition and relative impotrance of the genetic and of the environmental variation of the trait? Lush (1948) considers this point in a discussion of non-linear genotype environment interactions.

The objective of the present study was to estimate heritability of weaning weight in herds subjected to different environmental conditions.

Material

The data anlyzed in this study are the weaning weights of 577 calves produced by two grade Hereford herds maintained by the University of California at the San Joaquin Experimental Range (operated by U. S. Forest Service) in the foothills of the Sierras east of Madera, California. A detailed description of the constitution and management of these herds has been presented by Wagnon *et al.* (1942). A brief summation of the management of these herds is as follows:

In June 1935, 70 head of medium to good grade 2-year old bred Hereford heifers were brought to the Range. They were run together and received supplemental feed during their first calving, which occurred during the ensuing fall and winter. In January 1936, the heifers and their calves were divided into two comparable groups, A and B. Herd A received supplements during the late summer, fall, and winter until adequate new green forage became available, while Herd B received no

[1] San Joaquin Experimental Range, O'Neal's, California.
[2] Davis, California.
[3] In cooperation with the U.S.D.A. under Western Regional Project W-1 on beef cattle breeding research.

supplements except in emergency to stop death losses. From the advent of new forage growth until after the calves were weaned the fore part of July neither herd received supplements. The dry forage of the Range was found to be deficient in crude protein and at times in phosphorus. Starting with the germination of the new forage crop and until the new forage growth became adequate in abundance there was also a deficiency of total energy intake. The A Herd cows received supplements during the period of deficient nutrition in amounts judged necessary to meet the deficiencies occurring, and the resulting benefits were determined by a comparison of the average cow's production with the cost of her supplementation. Herd B was used as a control.

Superimposed upon this experiment was one in which a study was made of the effects of various levels of intensity of grazing. Six pastures were established (Talbot and Biswell, 1942) and were grazed during the period when no supplements were fed. Cows from both the A and B herds were assigned in as equal a manner as possible to each pasture. Once a cow was assigned to a pasture she was returned to that pasture each successive year as long as she was retained in the herd. Intensity of grazing of the pastures was rated as follows: close, moderate to close, moderate, light to moderate, and (two pastures) light (Bentley and Talbot, 1951).

The breeding of the two herds were similar in that the same bulls from the University's registered Hereford herd were used on each herd. The breeding season was January through the following April, and calves were identified as to sire and dam. Data from eleven calf crops, 1936 through 1946, were used in this study. Cattle weights were regularly taken at the close of the supplemental feeding period, the start of rapid forage growth, end of the green forage period, when the calves were weaned, start of the supplemental period, and prior to the start of the calving period. At times weighings were made at other periods. Calves were weaned at about 240 days of age. A calf's weaning weight was adjusted to 240 days of age by taking a linear interpolation or extrapolation based on its weaning weight and its weight at a previous weighing which as a rule was about a month earlier.

The extent to which the treatment difference affected the average performance of each of the two herds is indicated by the material presented in figure 1 and in table 1. Figure 1 presents a comparison of the weights of cows in the two herds. Table 1 presents a series of statistics comparing various aspects of cow productivity in the two herds.

TABLE 1. A COMPARISON OF THE PRODUCTIVITY OF HERD A AND HERD B COWS

	Herd A	Herd B
Percentage of pregnancies	88.9	75.4
Percentage calf crop weaned	81.0	66.4
Average weaning weight, lb.	462	408
Average calf production per breeding cow, lb.	373	274

Analysis of Data

Adjustment of Data for Specified Effects

From the start of the green forage season to weaning time the cows were in six different pastures, as previously described. Cows from the A and B herds were distributed among the pastures as proportionately as possible. During the green forage period the average daily gain of the calves in each herd was the same (table 2).

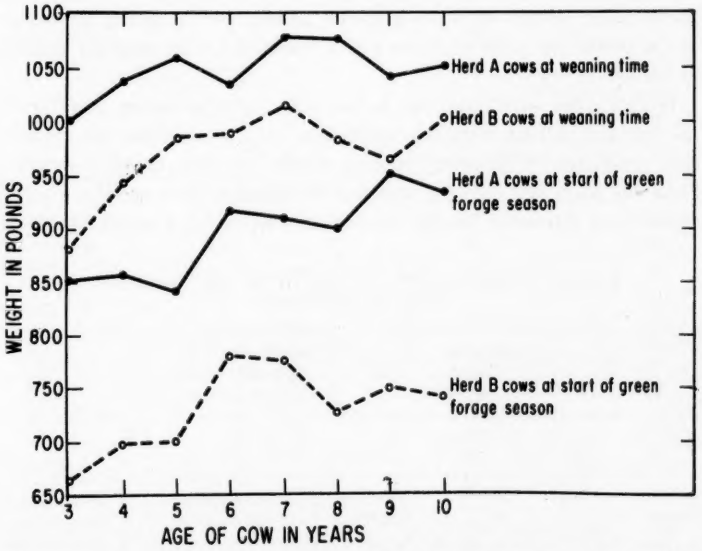


Figure 1. A comparison of average weights of cows in Herds A and B.

TABLE 2. AVERAGES OF WEIGHT AND DAILY GAIN OF CALVES BASED ON RAW DATA

Herd	Number of calves	Weight at start of green forage season	Daily gain during green forage season	240 day weaning weight [a]
		lb.	lb./day	lb.
A	321	195.8	1.76	468.4
B	256	144.3	1.76	423.4

[a] Observed weaning weight adjusted to 240 days of age by interpolation or extrapolation based on a calf's two successive weights around weaning time.

The data were standardized for differences due to year of birth, sex, age of dam and pasture. The correction factors were estimated by the method of least squares using a model similar to that described by Rollins and Guilbert (1954). The estimated correction factors are presented in tables 3 and 4. After standardizing the data repeatability estimates and heritability estimates were made for each of the herds. These estimates are presented in table 5.

The repeatability of weaning weight is the intra-class correlation of the weaning weights of a cow's calves, (Lush, 1945), and is an index of the predictive value of a cow's first record for indicating her future performance.

Heritabilities were estimated in two ways: (1) by taking four times the paternal half sib intraclass correlation; (2) by doubling the regression coefficient of offspring weaning weight on dam weaning weight. Since the dams had varying numbers of offspring the regression coefficients were estimated by the method developed by Kempthorne and

TABLE 3. CORRECTION FACTORS FOR DIFFERENTIAL PASTURE EFFECTS

Pounds to be added	to	The weaning weight of a calf reared in pasture No.
14		1
0		2
65		3
20		4
36		5
20		6

Tandon (1953), which enables one to assign the best weights to the information contributed by dams with varying numbers of offspring.

Results and Discussion

The heritability estimates presented in table 5 are inconsistent. Based on the offspring-dam regression method the estimate for Herd A is significantly greater than that for Herd B at the one percent level of probability. Based on the paternal half sib method the estimate for Herd B is greater than that for Herd A. This latter difference is con-

TABLE 4. CORRECTION FACTORS USED IN STANDARIZING WEANING WEIGHTS IN HERDS A AND B

Correction for:	Class	Pounds to be added	
		Herd A	Herd B
Sex	Steer calves	0	0
	Heifer calves	31	18
Age of dam at calving, years	3	50	48
	4	32	29
	5	17	14
	6	7	4
	7	1	0
	8	0	0
	9	3	6
	10	11	17
Year (Based on green forage season)	1937	25	0
	1938	27	95
	1939	25	33
	1940	0	3
	1941	9	20
	1942	39	38
	1943	49	51
	1944	84	107
	1945	40	47
	1946	63	61
	1947	65	89
Age of calf at start of green forage period	For each day of age over 80	.26	.30
	For each day of age under 80	—.26	—.30

sidered not significant since there is a large overlap in the 95 percent confidence intervals of the intraclass paternal half sib correlations on which the estimates are based. The upper limit for the intraclass correlation for Herd A is .13 while the lower limit for that of Herd B is .01.

In doubling the offspring-dam regression to obtain an estimate of heritability the assumption is that the regression is due to genetic causes solely. If some environmental factors are contributing to the regression then the resulting heritability estimate will be biased.

TABLE 5. REPEATABILITY AND HERITABILITY ESTIMATES OF 240 DAY WEANING WEIGHT

			Data available for estimate		
		Estimate	Number of dams	Number of sires	Number of offspring
Herd A	Repeatability	.51	97		317
	Heritability (4 x paternal half sib correlation)	.09		23	313
	Heritability (2 x offspring-dam regression)	.84 ± .23	47		151
Herd B	Repeatability	.34	89		256
	Heritability (4 x paternal half sib correlation)	.54		22	256
	Heritability (2 x offspring dam regression)	−.13 ± .24	44		120

Since weights were available for dams at 27 months of age, it was decided to see if size of dam might enter into a path (environmental for the offspring) contributing to the regression in question. The hypothesis to be tested is diagrammed in figure 2.

Using the method of path coefficients (Wright, 1934) we have:

$$b = \tfrac{1}{2} g^2 + gag' p_{D'O} + p_{DD'} p_{D'O} = \tfrac{1}{2} g^2 + (gag' + p_{DD'}) p_{D'O} = \tfrac{1}{2} g^2 + r_{DD'} p_{D'O}$$

and thus

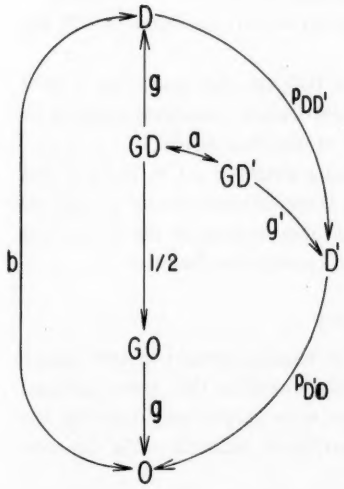
$$(1)\ g^2 = 2(b - r_{DD'} p_{D'O}).$$

$r_{DD'}$ and $r_{DO'}$, the correlations between D and D′ and O and D′, respectively, were estimated for Herds A and B:

	Herd A	Herd B
b	.42	−.06
$r_{DD'}$	.74	.27
$r_{OD'}$	.48	.18
$r_{DD'}r_{OD'}$	.36	.05

$p_{D'O} = r_{D'O} - \frac{1}{2}$ gag′ is the path coefficient of the path along which maternal effect due to size of dam operates. The requisite data are not extensive enough to warrant estimates of a and of g′, hence since the term $\frac{1}{2}$ gag′ cannot be determined it is not possible to evaluate $p_{D'O}$. Taking the correlations $r_{DD'}$ and $r_{OD'}$ at their face value we can set up limiting conditions on the value of $p_{D'O}$ and thus of g^2:

$r_{DD'} = gag' + p_{DD'}$ and $r_{OD'} = \frac{1}{2}$ gag′ + $p_{D'O}$
If gag′ = O then $p_{D'O} = r_{OD'}$
and from equation (1)
$g^2 = .12$ for Herd A and $-.22$ for Herd B.
If $p_{DD'} = O$ then $r_{DD'} = gag'$ and $p_{D'O} = r_{D'O} - \frac{1}{2} r_{DD'}$
then from equation (1)
$g^2 = .68$ for Herd A and $-.14$ for Herd B.



D = dam's weaning weight
GD = dam's genotype for weaning weight
O = offspring's weaning weight
GO = offspring's genotype for weaning weight
D′ = dam's weight at 27 months of age
GD′ = dam's genotype for weight at 27 months of age
a = correlation between GD and GD′
g = square root of heritability of weaning weight
g′ = square root of heritability of weight at 27 months of age
$p_{DD'}$ = path coefficient for non genetic path from D to D′
$p_{D'O}$ = path coefficient for path along which maternal effect of D′ on O operates
b = regression of O on D
(Note: b is used instead of r_{DO} in order to compensate for reduced variance of D due to selection of dams)

Figure 2. Path coefficient diagram analyzing the composition of the regression coefficient of offspring's weaning weight on dam's weaning weight.

Since heritability cannot be less than zero we know that in the case of Herd B the negative values of g^2 are due to sampling error and/or some bias in our estimating procedure. In the case of Herd A the heritability estimate which seemed suspiciously high before taking maternal effect into consideration has been reduced under both of the limiting conditions considered. It seems quite reasonable to assume that $p_{D \cdot O}$ and thus g^2 has a value intermediate to those considered above.

In summary, the following conclusion seems warranted: under some circumstances the dam's characteristics which exert a maternal effect on the weaning weight of her calf may be correlated with her weaning weight to such an extent as to seriously bias an estimate of heritability based on the equation $g^2=2b$.

In view of this, heritability estimates for weaning weight based on paternal half sib correlations would seem more reliable than those based on the regression of offspring on dam.

Since there is no evidence that the heritability estimates for Herds A and B are significantly different, an average of the two paternal half sib estimates is considered the best estimate of heritability of weaning weight that these data afford. This estimate is .30.

Knapp and Clark (1950) report a heritability estimate of .28 for weaning weight for range Herefords.

The experimental evidence does not indicate that operating a herd under the optimum or sub-optimum nutritional conditions existing in this experiment affects the heritability of weaning weight.

The estimated repeatability of weaning weight is .51 in Herd A and .34 in Herd B. The difference between these estimates is not considered statistically significant since there is a large overlap in the 95 percent confidence intervals of the intraclass correlations involved.

Summary

A genetic analysis has been made of weaning weight in two experimental range herds, A and B, of similar breeding that were managed alike except that in Herd A the cows were supplemented during the fall and winter when the range was nutritively deficient, while the cows in Herd B were not supplemented.

The data were standardized for differential effects of pasture, year, sex, age of calf at weaning and age of dam.

Heritability of weaning weight was estimated to be .30. The experi-

mental evidence indicated that the difference in nutritive level of the two herds did not influence the heritability of weaning weight.

Repeatability of weaning weight was estimated to be .51 in Herd A and .34 in Herd B.

Literature Cited

Bentley, J. R. and M. W. Talbot. 1951. Efficient use of annual plants on cattle ranges in the California foothills. U.S.D.A. Circ. 870:1.

Kempthorne, O. and O. B. Tandon. 1953. The estimation of heritability by regression of offspring on parent. Biometrics 9:90.

Knapp, Bradford Jr. and R. T. Clark. 1950. Revised estimates of heritability of economic characteristics in beef cattle. JOURNAL OF ANIMAL SCIENCE 9:582.

Lush, Jay L. 1945. Animal Breeding Plans. 3rd Ed. viii, 443 pp. The Collegiate Press, Ames, Iowa.

Lush, Jay L. 1948. The Genetics of Populations. (Mimeographed) Ames, Iowa.

Rollins, W. C. and H. R. Guilbert. 1954. Factors affecting the growth of beef calves during the suckling period. JOURNAL OF ANIMAL SCIENCE 13:517.

Talbot, M. W. and H. H. Biswell. 1942. The forage crop and its management. In: Hutchison, C. B. and E. I. Kotok. The San Joaquin Experimental Range. Calif. Agr. Exp. Sta. Bul. 663:13.

Wagnon, K. A., H. R. Guilbert and G. H. Hart. 1942. Experimental herd management. In: Hutchison, C. B. and E. I. Kotok. The San Joaquin Experimental Range. Calif. Agr. Exp. Sta. Bul. 663:50.

Wright, Sewall. 1934. The method of path coefficients. Ann. Math. Stat. 5:161.

ALTERATION OF OVARIAN ACTIVITY BY HYSTERECTOMY [1]

J. N. WILTBANK [2] AND L. E. CASIDA [3]

University of Wisconsin

IT has been demonstrated that the removal of the uterus in some species (guinea pig: Loeb, 1927; rabbit: Asdell and Hammond, 1933; Loeb and Smith, 1936; Gillard, 1937; Chu *et al.*, 1946; rat: Bradbury, 1937; Hechter *et al.*, 1940) causes maintenance of the corpus luteum for a period of time which approaches the normal length of pregnancy. Other workers have failed in an attempt to show that the removal of the uterus has an effect on the maintenance of the corpus luteum. Hartman (1925) removed the uterus from the opossum and concluded that removal has no effect on the corpus luteum. Burford and Biddle (1936) noted no effect on the corpora lutea when the uterus is removed from the monkey. The purpose of this study was to determine if removal of the uterus in the cow and ewe would alter ovarian activity.

Materials and Methods

Ewes

Midventral laparotomies were performed on the ewes 3 to 8 days after heat, nembutal being used as an anesthetic. In ten ewes the uterus was removed as close to the cervix as possible. In six other ewes a control operation was performed. One uterine horn was removed from one of these control ewes and in the remaining animals the broad ligament was torn away from one uterine horn for approximately 2 to 3 inches with one oviduct being removed in the case of two of the animals. The corpora lutea in six of the hysterectomized animals and five control ewes were marked with India ink by forcing the ink dropper from the ink bottle into the center of the corpus luteum. In the remaining animals the position of the corpus luteum was merely

[1] Paper No. *590*, Department of Genetics, University of Wisconsin. Published with the approval of the Director of the Agricultural Experiment Station. This work was done under a cooperative agreement between the Wisconsin Agricultural Experiment Station and the Dairy Husbandry Research Branch, U.S.D.A. It has been supported in part by grants from Badger Breeders' Cooperative, Consolidated Breeders' Cooperative, East Central Breeders' Cooperative, Southern Wisconsin Breeders' Cooperative and Tri-State Breeders' Cooperative.

[2] Agent of the Dairy Husbandry Research Branch, U.S.D.A.

[3] The authors wish to acknowledge aid in surgery given by N. C. Buch, A. S. El-Sheikh, H. W. Hawk, C. V. Hulet, H. E. Kidder, C. A. Kiddy and R. V. Short.

noted and recorded at the time of the operation. The four hysterectomized ewes and the control ewe in which corpora lutea were not marked were slaughtered 20 days after the preoperative heat. Two of the remaining hysterectomized ewes were slaughtered 50 days after the preoperative heat, one at 75 days, one at ninety days and two at 100 days.

A vasectomized ram with fresh paint on his brisket ran with the ewes. Any ewe which was found with paint on her rump was checked using another vasectomized ram. A ewe was considered to be in heat if she would stand to be served by the latter ram.

Heifers

The uteri were removed from four of the heifers by a midventral laparotomy using a general anesthetic. Because of the difficulty encountered in removing the uterus completely by this method, the uteri from the other two heifers were removed by means of a high lumbar incision using a local anesthetic. The complete uterus was removed from only four of the heifers, a part of the uterine tissue was left in the other two. All operations were performed five to twelve days after heat. The corpus luteum in five of these heifers was marked with India ink at the time of the operation using the same method as employed in the ewes. In the other heifer the position of the corpus luteum was merely noted and recorded.

The heifers were checked twice daily for heat by the use of a spayed heifer which was injected with estrogen periodically. A heifer was considered in heat when she would stand and let other heifers mount her.

Results

Ewes

The complete removal of the uterus in the ewes apparently prolonged the life of the corpus luteum in all cases (table 1). In the four ewes slaughtered twenty days after the preoperative heat no estrus was noted. The corpora lutea present in the ovaries of these ewes at slaughter were all well formed and were located at approximately the same position as noted at the time of hysterectomy. Two of the ewes (27 and 74) had a moderate amount of follicular development.

Two ewes were slaughtered approximately 50 days after the preoperative heat. Neither of these ewes showed signs of estrus during the interval between the operation and slaughter. Corpora lutea which

had India ink in the center were found on examination of the ovaries after the ewes were slaughtered. Very little follicular development was apparent in these two ewes.

Two ewes showed signs of estrus after the operation. One ewe would stand for the ram to mount and serve her. The other ewe would allow

TABLE 1. EFFECT OF HYSTERECTOMY ON OVARIAN FUNCTION IN EWES [a]

Ewe No.	No. days from heat to operation	No. days from preoperative heat to slaughter	No. days from preoperative to postoperative heat	Observations at slaughter
35	5	20	—	Corpus luteum 10 mm.
27	5	20	—	Corpus luteum 11 mm. 3 follicles, 5 mm.
21	6	20	—	Corpus luteum 11 mm.
74	6	20	—	Corpus luteum 11 mm. 7 mm. follicle.
196	4	52	—	Corpora lutea 11 and 10 mm. well marked.
1965	3	53	—	Corpora lutea 10, 11 and 10 mm. well marked.
44	3	76	72 [b]	Corpus luteum 10 mm. well marked. 10 mm. follicle.
85	3	89	87	No marked corpus luteum. 10 mm. lutenized follicle.
970	3	98	—	Well marked corpora lutea, 10 and 10 mm.
274	5	107	—	Well marked corpora lutea, 10 and 10 mm. Unmarked corpus luteum, 10 mm. 12 mm. follicle.

[a] Six ewes were laparotomized for controls. Five had the broad ligament torn; the other one had a uterine horn removed. Five of the ewes returned to heat 16 days after operative heat; the other 33 days after.

[b] Ewe was marked and would allow ram to mount but not long enough to complete service.

the ram to mount but not long enough for service to be completed. This activity in the latter was apparent 72 days after the preoperative heat. The ewe was killed 4 days after signs of estrus and a corpus luteum marked with India ink and a 10 mm. follicle were found in the ovaries. The other ewe was in estrus 87 days after the preoperative

heat and was killed 2 days later. No marked corpus luteum was present in the ovaries. The only apparent structure was a 10 mm. luteinized follicle.

The other two ewes were slaughtered approximately 100 days after the preoperative heat. No estrus was noted in either of these animals after the operation. Both of these ewes had two corpora lutea marked with India ink present when the ovaries were examined after slaughter. One ewe (No. 274) also had one corpus luteum present which was not marked. It is believed that this was overlooked at the time of the operation as it was very close to one that was marked. This ewe also had a 12 mm. follicle present in the ovaries.

Only small amounts of uterine tissue were found at the time of slaughter in any of the 10 hysterectomized ewes.

All control ewes returned to heat. The ewe which had one uterine horn removed returned to heat sixteen days after the preoperative heat. She was slaughtered four days later. The corpus luteum present at that time was not well formed and appeared to be a new one. One ewe had a 33-day cycle; all others had 16-day cycles.

Heifers

Three of the four heifers in which the uterus was removed completely did not return to heat (table 2). However, one of these three heifers (No. 19) would ride other heifers a great deal at approximately 100 days but would not stand to be mounted. The three heifers were slaughtered at 46, 98, and 154 days after the preoperative heat.

The corpus luteum in the heifer slaughtered 46 days after heat was not marked at the time of hysterectomy. The corpus luteum at time of slaughter was thought to be the same as the one present at the time of the operation because it was on the same ovary, was not from a recent ovulation and the heifer showed no signs of estrus after the uterus was removed. Its position in the ovary at the time of slaughter could not be ascertained accurately as it occupied most of the ovary. Large well formed corpora lutea which were marked in the center with India ink were found in the other two heifers at the time of slaughter. The corpora lutea in all three of these heifers appeared to be functional. There was a moderate amount of follicular development in all the heifers with the heifer which showed the subestrus having the largest amount. This latter heifer also had a corpus luteum which was not marked at the time of the operation. The unmarked corpus luteum was near the mesovarium and was very close

to the marked one so it is believed that it was unnoticed at the time of the operation.

The other heifer in which the uterus was completely removed returned to heat and was slaughtered 27 days after the preoperative heat. No uterine tissue was found. A well formed corpus luteum well

TABLE 2. EFFECT OF HYSTERECTOMY ON OVARIAN FUNCTION IN HEIFERS

Heifer number	Extent of removal	No. days from heat to operation	No. days from pre-operative heat to slaughter	No. days from pre-operative to post-operative heat	Observations at slaughter
85	Complete	7	46	—	Corpus luteum (30 mm.) well formed. Largest follicle 16 mm.
1	Complete	8	98	—	Corpus luteum (20 mm.) marked with India ink. Largest follicle 15 mm.
19	33 mm. of uterine tissue left	5	154	—	Corpus luteum (22 mm.) marked with India ink. Largest follicle 20 mm. One unmarked corpus luteum, 17 mm.
99	Complete	10	27	27	Well marked corpus luteum, 22 mm. Largest follicle 60 × 90 × 60.
30	Approx. 5" of uterine tissue left	10	83	49	No marked corpus luteum.
35	Approx. 8" of uterine tissue left	12	102	33	No marked corpus luteum.

marked with India ink was present. There was also present an extremely large follicular cyst (measuring 60 x 90 x 60 mm.).

The two heifers in which the uterus was not completely removed returned to heat; one at 49 days after the preoperative heat, the other at 33 days (table 2). The one which returned at 33 days had the largest amount of uterine tissue present, approximately eight inches (3.5 inches of each uterine horn plus 1 inch of uterine body) as compared to five inches (2 inches each uterine horn plus uterine body)

in the other heifer. The ovaries in the former could be palpated and the corpus luteum regressed approximately three days prior to her return to heat. She did not ovulate at this heat period but the follicle grew to a large size and became "cystic." She, however, did ovulate at a later date. The other heifer apparently ovulated at the first heat after the operation.

Discussion

The corpora lutea were maintained as anatomical structures in most of the hysterectomized animals past the normal time of regression. There was, however, individual variation. It was not determined if the corpora lutea which were maintained were functional. The fact that most of the hysterectomized animals did not return to heat could at least be considered presumptive evidence that they were functional. But the endocrine activity of these corpora lutea may not be at the same level as in the intact animals. The fact that one hysterectomized heifer returned to heat with a large corpus luteum present, another heifer showed sub-estrus, one ewe returned to heat, and another ewe showed a great deal of interest in the ram but would not allow him to serve her points out that there is less luteal activity. Heifers with functional corpora lutea do not usually have the extreme follicular development noted in the one heifer.

The reason the corpus luteum does not regress in the absence of the uterus is not known. Robson (1937), Chu *et al.* (1946) and Lyons *et al.* (1943) have demonstrated that corpora lutea can be maintained in the rabbit and rat by injections of estrone. Pincus (1937) showed that injections of estrone in the intact rabbit increased the estriol in the urine but injections in the hysterectomized animal did not produce this effect. Hechter *et al.* (1940) pointed out that hysterectomy might lead to an accumulation of estrone which could cause maintenance of the corpora lutea. One other possible explanation advanced by Hechter *et al.* (1940) was that the uterus may produce a hormone which causes the corpora lutea to regress and in the absence of this hormone the corpora lutea are maintained.

The removal of approximately half of the uterus in one ewe did not prolong the life of the corpus luteum. Partial removal in case of the cow seemed to prolong the life of the corpus luteum. However, relatively smaller amounts of uterine tissue were left in the case of the cow. So removal of a greater portion in the ewe might prolong the life of the corpus luteum. Loeb (1927) found that when two-thirds to

three-fourths of the uterus was removed in the guinea pig the life of the corpora lutea was prolonged for a short period.

Summary

Complete removal of the uterus in the ewe or cow caused maintenance of the corpus luteum in most animals. The corpora lutea have been maintained for as long as 100 days in the ewe and 154 days in the cow. Longer intervals were not attempted. Removal of approximately half of the uterus in the ewe caused no delay in the return to estrus. Nearly complete removal of the uterus in the cow caused delay in the return to estrus. It was postulated that the corpora lutea, although maintained as anatomical structures, may not function at the same level as corpora lutea in intact animals.

Literature Cited

Asdell, S. A. and J. Hammond. 1933. The effects of prolonging the life of the corpus luteum in the rabbit by hysterectomy. Amer. Jour. Physiol. 103:600.

Bradbury, James T. 1937. Prolongation of the life of the corpus luteum by hysterectomy in the rat. Anat. Rec. Suppl. 70:51.

Burford, T. H. and A. W. Biddle, 1936. Effect of total hysterectomy upon ovary of the *macacus rhesus*. Surg. Gynec. & Obst. 62:701.

Chu, J. P., C. C. Lee and S. S. You. 1946. Functional relation between the uterus and the corpus luteum. Jour. Endocrin. 4:392.

Gillard, J. L. 1937. The effect of hysterectomy on mammary gland development in a rabbit. Amer. Jour. Physiol. 120:300.

Hartman, C. G. 1925. Hysterectomy and the oestrus cycle in the opossum. Amer. Jour. Anat. 35:25.

Hechter, Oscar, Max Fraenkel, Maurice Lev and Samuel Soskin. 1940. Influence of the uterus on the corpus luteum. Endocrin. 26:680.

Loeb, Leo. 1927. The effects of hysterectomy on the system of sex organs and on their periodicity of the sexual cycle in the guinea pig. Amer. Jour. Physiol. 83:202.

Loeb, L. and Margaret G. Smith. 1936. The effect of hysterectomy on the duration of life retrogression of corpora lutea and secondary sex organs in the rabbit. Amer. Jour. Anat. 58:1.

Lyons, W. R., M. E. Simpson and H. M. Evans. 1943. Hormonal requirements for pregnancy and mammary development in hypophysectomized rats. Proc. Soc. Exp. Biol. & Med. 52:134.

Pincus, G. 1937. The metabolism of ovarian hormones, especially in relation to the growth of the fertilized ovum. Cold Spring Harbor Symp. Quant. Biol. 5:44.

Robson, J. M. 1937. Maintenance by oestrin of the luteal function in hypophysectomized rabbits. Jour. Physiol. 90:435.

CORRELATIONS BETWEEN AMBIENT TEMPERATURES VARYING FROM 60°–95° F. AND CERTAIN PHYSIOLOGICAL RESPONSES IN YOUNG DAIRY BULLS[1]

R. B. Casady, J. E. Legates and R. M. Myers

North Carolina State College

NUMEROUS references and reviews are available reporting the results of investigations which have been conducted on the effects of high environmental temperatures on dairy cows. The literature, however, reveals little information relating the relationships between ambient conditions and physiological responses in the dairy bull.

This paper presents data gathered in the course of experiments designed to study heat tolerance in dairy bulls and to evaluate the correlation between certain physiological responses and various ambient temperatures.

Experimental

The data presented were obtained from two separate experiments in two environmental chambers, described previously by Casady *et al.* (1953). The first experiment covered 8½ months, after which the bulls were placed on pasture for 5 months during the fall and winter. They were then returned to the chambers for the second experiment of 7½ months duration.

Four Holstein bulls from the College herd were used and assigned to the chambers at random. Those in chamber A for the first experiment will be referred to as bulls 3 and 4, those in chamber B as bulls 5 and 6. In assigning these bulls to the chambers, the bulls which occupied chamber A during the first experiment were randomly assigned within chamber B in the second experiment, and vice versa.

Bulls 3, 4, 5 and 6 were 17½, 17, 19 and 17½ months old respectively when placed on the first experiment and 31, 30½, 32½ and 31 months old respectively when placed on the second. Bulls 3 and 6 were fraternal twins. The bulls were fed approximately ten pounds of hay and one and one-half pounds of grain mix twice daily throughout both experiments except for a period during March 1953 when corn silage was substituted for hay at one of the two daily feedings.

[1] Approved for publication as paper No. 666 in the Journal Series of the North Carolina Agr. Exp. Sta., Raleigh.

The conditions to which the bulls were exposed and the duration of exposure are indicated in table 1. In all instances exposure at the various temperatures was continuous, e.g., for 24 hours per day. To minimize the effects of humidity, attempts were made to maintain a constant dew point temperature or absolute humidity. However, limitations of the conditioning equipment allowed an increase in absolute humidity at high temperatures (table 1). It is felt that the small increases were not significant in view of the low humidities involved.

TABLE 1. AVERAGE ENVIRONMENTAL CONDITIONS TO WHICH BULLS WERE EXPOSED

Duration of exposure (days)	Dry bulb temp. (° F.)		Dew point temp. (° F.)		Absolute humidity (mm. Hg.)		Relative humidity (%)	
	Chamber		Chamber		Chamber		Chamber	
	A	B	A	B	A	B	A	B
				Experiment 1				
29	59.8	60.0	52.9	52.8	10.0	10.0	78.4	76.4
38	70.2	69.3	55.0	55.1	11.0	11.0	58.5	60.4
29	81.1	80.8	55.9	55.2	11.5	11.0	41.9	42.0
50	84.5	85.1	55.6	54.3	11.5	10.5	36.9	34.8
47	90.0	90.0	58.7	58.7	13.0	13.0	35.3	34.6
36	95.1	95.1	63.1	63.0	14.5	14.5	35.2	35.1
				Experiment 2				
27	59.8[a]	60.6[a]	55.4[a]	55.1[a]	11.0[a]	11.0[a]	85.7[a]	82.6[a]
27	70.3	70.2	54.5	53.4	11.0	10.5	58.1	55.7
27	79.9	80.7	55.9	55.4	11.5	11.0	44.0	42.2
27	84.4	84.6	56.7	55.7	11.5	11.5	39.0	36.8
27	88.5	89.8	59.3	58.0	13.0	12.0	39.0	35.0
42	94.2	92.8	61.9	58.6	14.5	13.0	33.8	32.9

[a] Averages based on data of 21 days.

The data collected varied somewhat for the two experiments. During the first experiment, measurements of pulse rate, respiration rate, rectal temperature and rump skin temperature were made three times daily, at 6, 12, and 6. Pulse rates were determined by palpation of the femoral artery and respiration rates were determined by visual counts of flank movements. Skin temperatures were measured using a copper-constantan thermocouple and Rubicon temperature calibrated potentiometer.[2] The thermocouple was placed between the hairs of the coat to have it in contact with the skin surface, or as close thereto as possible. Measurements were taken on the right rump between the hooks and pins. Water consumption was metered and feed consumption determined by weigh-backs at each feeding. Air movement was recorded

[2] Manufactured by the Rubicon Company, Philadelphia, Pa.

once daily using a hot-wire anemometer,[3] and ranged between 15 and 50 feet per minute during both experiments. The chamber dry bulb and dew point temperatures were continuously recorded by Foxboro instru-

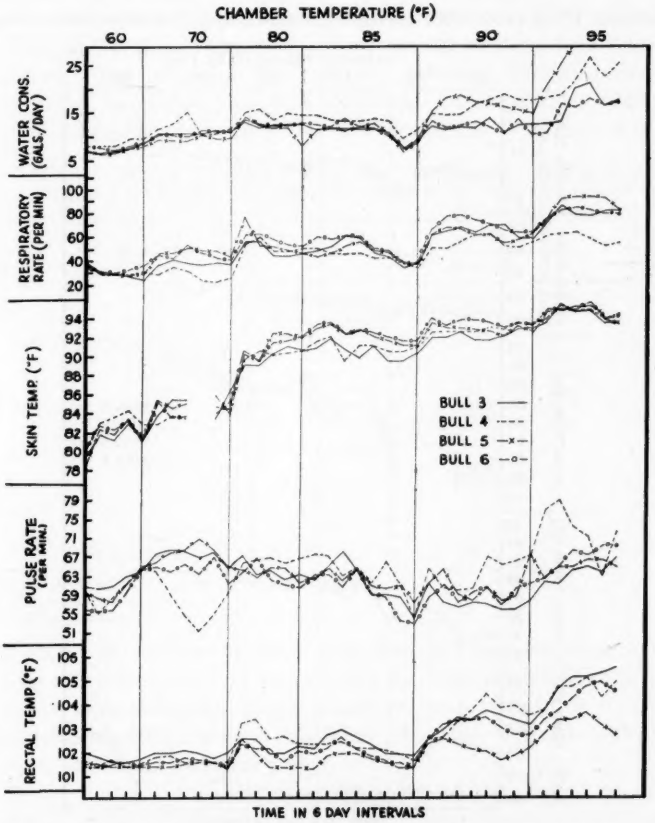


Figure 1. Graphic summary of data of experiment number 1 showing physiological responses of young dairy bulls under continuous exposure to increasing ambient temperatures.

ments.[4] During the latter part of the first experiment scrotal skin temperatures were also recorded in addition to the measurements noted above.

[3] Alnor Velometer, Illinois Testing Laboratories, Inc., Chicago, Ill.
[4] Manufactured by the Foxboro Company, Foxboro, Mass.

During the second experiment, measurements of respiration rate, rectal temperature, rump skin temperature and scrotal temperature were made twice daily, at 6 a.m. and 5 p.m., since evidence indicated that two readings per day were sufficient to indicate the animal's response. Pulse rates were not determined during this experiment since

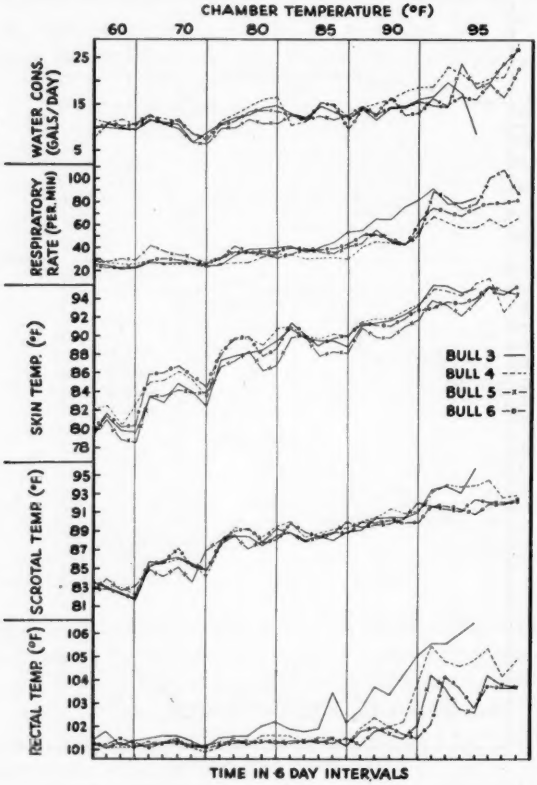


Figure 2. Graphic summary of data of experiment number 2 showing physiological responses of young dairy bulls under exposure to increasing ambient temperatures.

the results of the first experiment showed no significant correlation between pulse rate and the environmental conditions (table 4).

Study of the data from the first experiment revealed (figure 1), that during each treatment period there was an initial response, almost

immediately after the change from the previous temperature, followed by a leveling off or period of acclimatization. Therefore, in order to distinguish the length of time during a treatment when the physiological response might be considered indicative of the bull's reaction to that environment, each treatment period was divided into subperiods of six days each and the various response data analyzed by analysis of variance. The results of these analyses indicated that the period by subperiod interaction was least significant for the various responses during the second two subperiods, i.e., during the 7–18 days inclusive

TABLE 2. MEAN PHYSIOLOGICAL RESPONSES OF YOUNG DAIRY BULLS EXPOSED TO VARYING AMBIENT TEMPERATURES

Treatment	Av. chamber temp.	Rectal temp.	Resp. rate	Rump skin temp.	Water consumption	Pulse rate	Daily wt. gain or loss [a]
	° F.	° F.	/min.	° F.	gal.	/min.	lb.
			Experiment 1				
1	59.3	101.5	30.1	82.2	7.1	57.5	+0.75
2	69.2	101.8	42.8	84.1	10.5	64.6	+2.18
3	80.5	102.3	57.3	90.6	12.7	64.8	+1.62
4	84.7	102.4	54.6	92.2	12.3	64.8	+0.82
5	89.7	103.0	68.1	93.2	14.0	59.5	−0.15
6	95.1	104.3	81.8	95.5	20.0	68.5	−1.09
			Experiment 2				
1	60.7	101.3	26.6	80.8	10.1	83.3[c]	+2.01
2	70.5	101.4	29.2	84.9	10.8	85.8	+0.01
3	80.1	101.5	34.1	88.9	12.2	88.7	+2.87
4	84.1	101.5	36.2	89.5	13.0	88.5	+0.86
5	89.5	102.5	52.1	91.1	14.1	90.2	−0.07
6	94.7	104.4	71.5	94.0	18.9	92.6	−1.65[b]

[a] Based on weight change for entire treatment period.
[b] Based on data of 3 bulls.
[c] Scrotal skin temperatures in lieu of pulse rates.

of each treatment period. These subperiods indicated the response pattern, and non-significance showed that the response during those subperiods was essentially stable. Therefore, data for further statistical analysis from both experiments were taken only for the 7–18 days inclusive of each treatment period.

Results

The trend in physiological responses to increasing environmental temperatures are illustrated in figures 1 and 2, with the mean response for the 7–18th days of each treatment period for all bulls presented in table 2. The results show that in the first experiment, increases in respiratory rate, pulse rate, skin temperature and water consumption preceded those of rectal temperature. Pulse rate and water consumption showed a marked rise at chamber temperatures of 70° F. and again at

95° F., while respiratory rates showed marked increases at 70°, 80°, 90° and 95° F. Rectal temperatures and rump skin temperatures, on the other hand, did not show marked responses to increased chamber temperature until the latter reached 80° F., above which there was a steady rise with increasing ambient temperature through 95° F.

During the second experiment there was no marked response in either rectal temperature or respiratory rate until the chamber temperature reached 90° F. This delay or absence of marked responses in rectal temperature and respiratory rate may be a reflection of the increased

TABLE 3. ANALYSIS OF VARIANCE OF PHYSIOLOGICAL RESPONSES IN YOUNG DAIRY BULLS EXPOSED TO VARYING AMBIENT TEMPERATURES

Source	d.f.	Rectal temp. MS	Respiratory rate MS	Pulse rate MS	Water consump. MS	Rump skin temp. MS
			Experiment 1			
Total	47	1.04	332.05	25.01	21.71	24.62
Bulls (B)	3	1.47	302.66	5.13	21.54	1.96
Treatments (T)	5	8.08**	2661.55**	129.72**	146.50**	225.00**
B x T	15	0.17*	72.51**	28.00**	11.73**	0.60
Within B x T	24	0.06	12.63	3.81	1.97	0.72
			Experiment 2			
Total	47	1.53	280.04	9.44[a]	11.82	19.68
Bulls (B)	3	1.85	192.07	1.82	12.38	6.39
Treatments (T)	5	12.06**	2351.97**	84.60**	79.16**	175.51**
B x T	15	0.33**	43.12**	0.63*	2.39	0.91
Within B x T	24	0.05	7.47	0.25	3.62	0.60

* Significant at the 5 percent level of probability.
** Significant at the 1 percent level of probability.
[a] Values for scrotal skin temperature instead of pulse rates.

age of the bulls, since there is evidence (Bonsma, 1947, 1953) that thermoregulation in young animals is not as efficient as in the adult. During the second experiment these animals were 14 months older than during comparable stages of the 1st experiment, and approximated 3 years of age. Rump skin temperature, scrotal skin temperature and water consumption showed a steady increase for each 10° F. rise in chamber temperature.

Gains in weight were maintained when the chamber temperature was 85° F. or below in both experiments, but daily losses occurred during exposure to 90° and 95° F. (table 2).

The analysis of variance showed no significant bull differences for the various responses in either experiment. This statistical nonsignificance must be interpreted in the light of the small number of bulls

TABLE 4. CORRELATIONS BETWEEN CHAMBER TEMPERATURE AND PHYSIOLOGICAL RESPONSES IN YOUNG HOLSTEIN BULLS

	Experiment 1					Experiment 2				
Bull No.	Rectal temp.	Resp. rate	Pulse rate	Rump skin temp.	Water cons.	Rectal temp.	Resp. rate	Rump skin temp.	Scrotal skin temp.	Water cons.
3	0.87*	0.98**	—0.11	0.99**	0.89**	0.76*	0.89	0.99**	0.97**	0.86*
4	0.86*	0.90**	0.78*	0.98**	0.91**	0.72	0.80*	0.99**	0.97**	0.82*
5	0.85*	0.91**	0.28	0.99**	0.87*	0.73	0.81*	1.00**	0.99**	0.86*
6	0.93**	0.98**	0.61	0.98**	0.93**	0.77**	0.89**	0.97**	0.98**	0.97**
All bulls	0.89**	0.97**	0.58	0.99**	0.91**	0.75*	0.86*	0.99**	0.99**	0.88**

* Significant at the 5 percent level of probability.
** Significant at the 1 percent level of probability.

involved, since the mean squares do suggest the existence of real differences among bulls. However, highly significant treatment differences were apparent in all cases (table 3). Bull by treatment differences were significant for all measurements except for skin temperatures and water consumption in the second experiment.

Correlations between chamber temperatures and the various physiological responses (table 4) were significant for all measurements except pulse rates in the first experiment. In the second experiment the correlation coefficients were smaller but still showed significance, except

TABLE 5. CORRELATIONS BETWEEN RUMP SKIN TEMPERATURE, RECTAL TEMPERATURE, SCROTAL TEMPERATURE AND CHAMBER TEMPERATURE IN YOUNG BULLS EXPOSED TO INCREASING AMBIENT TEMPERATURES

		Correlation between:				
Bulls	Expt. No.	Chamber temp. and rump skin temp.	Rectal temp. and rump skin temp.	Chamber temp. and scrotal skin temp.	Rectal temp. and scrotal skin temp.	Chamber temp. and rectal temp.
3	1	0.99**	0.87**			0.87**
	2	0.99**	0.80*	0.97**	0.87**	0.76*
4	1	0.98**	0.89**			0.86**
	2	0.99**	0.75*	0.97**	0.82**	0.72
5	1	0.99**	0.78*			0.85*
	2	1.00**	0.73	0.99**	0.76*	0.73
6	1	0.98**	0.89**			0.93**
	2	0.97**	0.71	0.98**	0.71	0.77*
All bulls	1	0.99**	0.91**			0.89**
	2	0.99**	0.76*	0.99**	0.81*	0.75*

* Significant at 5 percent level of probability.
** Significant at 1 percent level of probability.

for the correlations between chamber and rectal temperature for bulls 4 and 5. The low correlations between pulse rate and chamber temperature prompted the dropping of this measurement during the second experiment.

To assess the relative influence of chamber and rectal temperature upon skin temperatures, correlations between these measurements were determined for each experiment (table 5). It is obvious that rump and scrotal skin temperatures, as measured, are more closely associated with chamber temperature than with rectal, or body temperatures. Correlations on pooled data for all bulls were run between rectal tem-

peratures and the other physiological responses for each treatment period (table 6). The results disclosed lack of significance in most cases, and showed consistent relationships either between bulls or within

TABLE 6. CORRELATIONS BETWEEN RECTAL TEMPERATURE AND OTHER PHYSIOLOGICAL RESPONSES (VARIABLES) FOR ALL BULLS ACCORDING TO TREATMENTS

Variable	Source	Treatments					
		60° F.	70° F.	80° F.	85° F.	90° F.	95° F.
		Experiment 1					
Respiratory rate	Between bulls	−0.62	−0.62	−0.01	0.48	0.19	−0.72
	Within bulls	−0.23	0.58*	0.81**	0.85**	0.74**	0.04
Pulse rate	Between bulls	0.76	0.02	0.88*	0.59	−0.43	0.33
	Within bulls	1.00**	0.46	−0.08	0.08	−0.42	0.41
Rump skin temp.	Between bulls	−0.51	−0.54	−0.15	−0.65	0.02	0.43
	Within bulls	0.83**	−0.07	−0.13	−0.68**	0.66**	0.13
Water consumption	Between bulls	0.17	0.45	0.87*	0.09	−0.99**	−0.72
	Within bulls	0.41	0.25	−0.40	−0.22	0.16	0.38
		Experiment 2					
Respiratory rate	Between bulls	−0.15	−0.29	0.34	0.61	0.92*	−0.07
	Within bulls	0.36	0.12	0.13	0.50	0.73**	0.87**
Scrotal skin temp.	Between bulls	0.85	0.18	−0.49	−0.47	0.52	0.80
	Within bulls	−0.45	0.58*	−0.20	0.10	0.46	0.18
Rump skin temp.	Between bulls	−0.29	−0.61	−0.45	0.37	0.46	0.97**
	Within bulls	−0.39	0.67**	−0.32	−0.15	0.39	0.45
Water consumption	Between bulls	−0.21	−0.46	0.02	0.33	−0.51	0.17
	Within bulls	−0.06	0.08	−0.58*	0.80**	0.15	−0.61

* Significant at the 5 percent level of probability.
** Significant at the 1 percent level of probability.

bulls, only in correlations between respiratory responses and rectal temperatures. Although the relationship was not precisely comparable in both experiments, rectal temperature and respiratory rate were most closely associated when the air temperature ranged from 80° to 90° F.

Discussion

Most experiments concerned with reactions to thermal stress, have been concerned with attempts to determine which mechanisms or physiological responses are most indicative of an animal's reaction to high temperatures. Considerable speculation has arisen from such studies, though it has been generally conceded that rectal temperature and respiratory rate responses come the closest to revealing an animal's physiological reactions to heat stress.

One question which arises is do the various physiological responses directly reflect actual changes in the animal's internal environment or are they more closely associated with external changes?

Field studies by Johnston and Branton (1952) have indicated significant correlations between body temperature and ambient temperature only when the ambient temperature was within 40°–60° F. and 70°–80° F. intervals. Respiration rate was significantly correlated with ambient temperature and humidity, except maximum temperature within the 80°–85° F. and 85°–90° F. intervals. Pulse rate was significantly correlated with mean daily temperature within the 85°–90° F. interval. Later investigations by Johnston and Branton (1953) and Johnston *et al.* (1954) showed that only respiration rate was consistently related to climatic conditions, with absolute humidity and mean environmental temperature being most highly correlated with respiratory responses. Changes in respiration rate, flank skin temperature and scrotal length on exposure to heat stress did not bear much relationship to "heat tolerance." In addition, McDowell *et al.* (1953) in chamber studies on respiratory activity as an index of heat tolerance conclude that it was not significantly correlated with rectal temperature under the conditions of their experiment. Similar conclusions are drawn by Blakley and Findlay (1955a, 1955b) from results of chamber experiments with young Ayrshire bulls.

One might assume that marked physiological responses to increases in environmental temperatures are reflections of changes in internal environment and stress, as indicated by increased body temperatures. However, a closer look at the data (tables 4, 5, 6) reveals that the correlations between the chamber temperature and responses other than rectal temperature, are higher than those between rectal temperature and the same responses. One exception to this seems to be water consumption which is more closely related to rectal temperature than chamber temperature (table 4).

The fact that respiratory rate and skin temperature fluctuate more readily with room temperatures than does rectal temperature, and precede responses of the latter to increased air temperatures (figures 1, 2, table 2), suggests that responses of respiratory rate and skin temperatures are corrective mechanisms elicited to compensate for deteriorative processes and to allay stress, rather than indications of stress *per se*.

In addition, table 6 shows that, during experiment 1, the within bull correlations between respiratory rates and rectal temperatures were negative or insignificant at chamber temperatures of 60° and 95° F. This, and figures 1 and 2, suggest that at the lower air temperatures respiratory rates were increasing while rectal temperatures remained fairly constant, and at the highest air temperatures respiratory rates were leveling off while rectal temperatures were continuing to rise. In experiment 2 respiratory rates continued to rise at maximum air temperatures which indicates a greater physiological adaptive mechanism in the older bulls. Between-bull correlations between rectal temperatures and respiratory rates reveal the individual variations encountered. At high temperatures bulls with highest respiratory rates did not tend to have the highest rectal temperatures and vice versa. The same general relationships hold true between rump skin temperatures and rectal temperatures. At temperatures above 90° and 95° F. respiratory rates are not closely associated with rectal temperature, possibly because of physiological limits in respiration being reached before maximums, or critical levels, of rectal temperature.

Responses of rump skin temperature and scrotal temperatures may be considered more as reflections of ambient temperature than as indices of internal physiological changes, since under the conditions of these experiments they were not as closely correlated with rectal temperature changes as with changes in air temperature.

Summary

In two experiments, four Holstein bulls were subjected to continuous exposure in environmental chambers to air temperatures of 60°, 70°, 80°, 85°, 90° and 95° F., at absolute humidities of 10.0 to 14.5 mm. Hg. Treatment periods at each of the above temperatures ranged from 29 to 50 days in duration.

Correlations for each treatment period, between rectal temperatures and the physiological responses of respiratory rate, rump skin temperature and scrotal skin temperature, were lower than the correlations

between chamber temperature and the same responses. On the other hand, water consumption was more closely related to rectal temperature than chamber temperature.

Respiratory rates were most closely associated with rectal temperatures at air temperatures of 80°–90° F. At temperatures above 90°–95° F. respiratory rates were not closely associated with rectal temperatures and could not be used as indices of thermal stress.

The results indicate that skin temperature was not a precise reflection of changes in the animal's internal environment.

A possible age difference in response to high ambient temperatures was exhibited by a delay in responses of respiratory rate and rectal temperature to increased ambient temperature during the second experiment. There was no marked response in either variable until the ambient temperature reached 90° F. as compared to initial responses at 70°–80° F. in the first experiment.

Literature Cited

Beakley, W. R. and J. D. Findlay. 1955. The effect of environmental temperature and humidity on the skin temperature of Ayrshire calves. Jour. Agr. Sci. 45: 353.

Beakley, W. R. and J. D. Findlay. 1955. The effect of environmental temperature and humidity on the respiration rate of Ayrshire calves. Jour. Agr. Sci. 45: 452.

Bonsma, J. C. 1947. The influence of climate on animal production and its effects on human nutrition. The Leech p. 9, April.

Bonsma, J. C., J. Van Marle and J. H. Hofmeyr. 1953. Climatological research on animal husbandry and its significance in the beef cattle production in colonial territories, Empire Jour. Exp. Agr. 21:154.

Casady, R. B., R. M. Myers and J. E. Legates. 1953. The effect of exposure to high ambient temperature on spermatogenesis in the dairy bull. Jour. Dairy Sci. 36:14.

Johnston, J. E. and C. Branton. 1952. Relationship of maximum daily air temperature and humidity to physiological reactions of dairy bulls. Jour. Dairy Sci. 35:489.

Johnston, J. E. and Cecil Branton. 1953. Effects of seasonal climatic changes on certain physiological reactions, semen production and fertility of dairy bulls. Jour. Dairy Sci. 36:934.

Johnston, J. E., H. Kellgren, H. Naelapaa, J. B. Frye, Jr., J. J. Vizinat and B. Green. 1954. Effects of elevated temperatures and humidities on physiological response and semen production of Holstein, Brown Swiss, Jersey and Red Sindhi crossbred bulls. (Unpublished).

McDowell, R. E., D. H. K. Lee, M. H. Fohrman and R. S. Anderson. 1953. Respiratory activity as an index of heat tolerance in Jersey and Sindhi X Jersey (F_1) crossbred cows. JOURNAL OF ANIMAL SCIENCE 12:573.

THE NUTRITIVE VALUE OF VARIOUS GRASSES AND GRASS-LEGUME MIXTURES [1]

W. E. WATKINS [2] AND JOSEPH V. KEARNS, JR.[3]

New Mexico Agricultural Experiment Station

DIGESTIVE studies were made with some introduced grasses and some of the permanent pasture mixtures in New Mexico. Included in the studies were crested wheatgrass *(Agropyron desertorum)* and western wheatgrass *(Agropyron smithii)*. Crested wheatgrass is well adapted to the cool, dry higher elevations of the Rocky Mountain states. This grass is characterized by early growth in the spring and late growth in the fall and produces a good volume of palatable, good quality forage. Western wheatgrass is distributed in the northern and central parts of the Great Plains. This grass is noted for its hardiness, drought resistance, and early spring growth. The mature plants cure well into a palatable nutritious forage that provides excellent winter grazing.

Other plants studied include Ladino clover *(Trifolium repens* var. Ladino). Alta fescue *(Festuca elatior* var. *arundiacea)*, coastal Bermuda *(Cynodon dactylon)* and alfalfa. This last group of forages were grown under irrigation.

Alta fescue is a special selection of tall fescue brought out at the Oregon Experiment Station. In Kentucky, a similar strain is known as Kentucky 31. Experimental results have indicated that Alta fescue may prove valuable for both pasture and hay under a great variety of conditions in both eastern and western sections of the United States because of its hardiness, disease resistance, and productive capacity.

Coastal Bermuda is a hybrid between Tift Bermuda and an introduction from South Africa, and was developed at the Georgia Experiment Station. This grass grows best at high temperatures, making little growth below 60° F. Coastal Bermuda is popular because of its resistance to disease, its high yield of palatable, good quality forage, and its resistance to drought.

The very low crude fiber content of some of the immature legumes, particularly Ladino clover, has been pointed out by Bell and Britton

[1] Journal Series No. 99, New Mexico Agricultural Experiment Station, State College, New Mexico.

[2] Nutrition chemist, New Mexico Agricultural Experiment Station, and professor of animal husbandry, New Mexico College of Agriculture and Mechanic Arts.

[3] Instructor of dairy husbandry, New Mexico College of Agriculture and Mechanic Arts.

(1939) as one of the factors favoring bloat in livestock. Digestion trials in which sheep were fed Ladino clover (Swift *et al.*, 1952; Forbes and Garrigus, 1950a, 1950) show quite high digestibility, with total digestible nutrients ranging from 60 percent to the high value of 77. Forbes and Garrigus also report that the total digestible nutrients from various grades of Kentucky fescue when fed to sheep ranged from 46 to 77 percent.

McCall *et al.* (1943) placed Alta fescue as slightly below average in total digestible nutrients (52.8) when compared with a variety of native and introduced grasses. These workers reported crested wheatgrasses which contained from 48 to 53 percent total digestible nutrients. Cook *et al.* (1954) report the digestibility of winter range plants determined by the lignin ratio technique with grazing sheep. Their digestion grazing study showed the total digestible nutrients of western wheatgrass to be 63.6 percent.

Walker and Hepburn (1955) report a close relationship between the gross digestible energy components of hay and the structural components represented by crude fiber, lignin, and cellulose. They further report that analyzing for lignin and cellulose is no more accurate for predicting digestibility of energy components than analyzing crude fiber by the usual method.

Swift *et al* (1952) report on the nutritive value of forages, giving energy and total digestible nutrients for a number of forages, including Kentucky blue grass, Ladino clover, orchard grass, brome grass, and timothy hay.

Experimental

Digestion trials were made by feeding the various grasses and mixtures to Rambouillet wethers. Four sheep were used in each metabolism trial. A seven-day preliminary period and a seven-day collection period were used. Feces and urine were collected in a manner as described by McCall *et al.* (1943). Blood samples were collected on the final day of each trial which were analyzed for calcium, phosphorus, and vitamin A.

The usual chemical analyses were made according to standard methods of the Association of Official Agricultural Chemists (1950). The samples were analyzed for lignin according to the method of Ellis *et al.* (1946).

Carotene analysis of the grass samples was made by the method of Thompson and Bickoff (1951). The phosphorus content of the blood plasma was determined by the method of Fiske and Subbarow (1925). Methods used in analyzing blood plasma for calcium, and urine for

calcium and phosphorus were those described by Hawk *et al.* (1937). The analysis of the blood plasma for vitamin A content was according to the method of Moore (1939).

Results and Discussion

The schedule of the various metabolism trials are presented in table 1. A preliminary period of seven days preceded the seven-day collection period. All grasses were cut at the stages of maturity indicated, cured, and fed in an air-dry condition.

TABLE 1. SCHEDULE OF METABOLISM TRIALS

Species of Forage	Date of Harvest	Quality	Digestion period	
			Start	End
Western wheatgrass	10/50	Mature	3/1	3/8/51
Crested wheatgrass	5/54	Immature	5/18	5/25/54
Crested wheatgrass	10/53	Old and new growth	12/9	12/16/53
Coastal Bermuda	6/53	Late growth stage	2/17	2/24/54
Coastal Bermuda 50%	6/53	Late growth stage	3/17	3/24/54
Alfalfa 50%	7/53	Early cut		
Alta fescue 75%	7/52	Early flowering stage	11/5	11/12/52
Ladino clover 25%	7/52	Early flowering stage		
Alta fescue 50%	7/52	Early flowering stage	11/18	11/25/52
Ladino clover 50%	7/52	Early flowering stage		
Alta fescue 25%	7/52	Early flowering stage	12/1	12/8/52
Ladino clover 75%	7/52	Early flowering stage		

The composition of the grasses and the grass mixtures are presented in table 2. Western wheatgrass was mature when harvested. One crested wheatgrass was composed of both old and new growth. The other grasses ranged from very immature to the late growth stage and represented rather high quality forage. The great difference in the nutritive value of forage plants at various stages of maturity are plainly shown here. The protein content of this series of grasses is quite high. The nitrogen-free extract content for most of the hays in this study rank favorably with those reported by Morrison (1948) for grass hays in general. Because the nitrogen-free extract is relatively slow to develop in the growing plant, it is a favorable indication to find this much easily digested carbohydrates along with a relatively high protein content in the rather immature grasses.

The lignin content of these grasses was rather low, except for the crested wheatgrass which contained old and new growth. The lignin

TABLE 2. COMPOSITION OF GRASSES AND GRASS MIXTURES

Species	Moisture	Ash	Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Calcium	Phosphorous
	%	%	%	%	%	%	%	%	%
Western wheatgrass	5.5	12.1	4.1	3.5	30.3	44.4	7.6	.16	.07
Crested wheatgrass, immature	6.8	8.5	19.8	3.2	19.8	41.9	5.2	.41	.19
Crested wheatgrass,[a] new and old	6.2	6.1	5.2	2.5	33.4	46.6	10.7	.18	.08
Coastal Bermuda	5.0	8.9	10.4	3.1	31.8	40.7	7.3	.29	.19
Coastal Bermuda 50 parts, alfalfa 50 parts	5.4	8.0	11.1	2.3	24.1	49.0	8.0	.65	.15
75% Alta fescue, 25% Ladino clover	4.4	11.7	14.6	2.3	22.3	44.7	5.7	.40	.23
50% Alta fescue, 50% Ladino clover	4.4	12.2	16.3	2.1	20.0	45.0	6.0	.83	.25
25% Alta fescue, 75% Ladino clover	4.7	9.1	19.4	1.9	19.6	45.4	6.0	1.30	.27

[a] Crested wheatgrass 51 percent old growth.

TABLE 3. DIGESTIBILITY, LIGNIN RECOVERY, AND TOTAL DIGESTIBLE NUTRIENTS OF GRASSES

		Crude protein	Ether extract	Crude fiber	N-free extract	Lignin recovery	Digestible protein	T.D.N.
		%	%	%	%	%	%	%
Western wheatgrass	Average	30.3	50.9	58.3	53.5	100.1	1.3	46.7
	High	35.3	55.1	63.0	51.9	105.7		
	Low	25.9	47.3	55.5	55.1	88.7		
Crested wheatgrass, immature	Average	84.8	62.2	79.3	81.5	83.8	16.8	71.1
	High	86.0	65.6	82.3	84.2	82.5		
	Low	83.1	55.6	74.3	78.6	77.4		
Crested wheatgrass, new and old	Average	45.7	35.8	58.6	51.8	81.7	2.4	48.2
	High	47.6	37.5	63.5	55.4	85.9		
	Low	44.7	34.1	54.2	47.2	74.3		
Coastal Bermuda	Average	75.0	75.3	67.5	55.1	97.7	7.8	57.0
	High	84.4	76.7	70.4	55.9	102.7		
	Low	70.4	71.8	65.7	54.3	91.9		
Coastal Bermuda, 50%, Alfalfa, 50%	Average	55.3	33.2	41.8	61.3	105.3	6.2	48.0
	High	63.5	41.9	46.5	63.8	113.2		
	Low	40.8	27.4	35.5	56.9	98.2		
Alta fescue 75%, Ladino clover 25%	Average	78.0	33.5	66.2	71.2	103.9	11.4	59.7
	High	79.9	40.0	70.6	74.3	125.9		
	Low	75.4	26.5	57.8	68.6	92.0		
Alta fescue 50%, Ladino clover 50%	Average	78.4	25.8	57.5	69.5	110.4	12.8	56.8
	High	80.1	35.0	61.6	72.0	124.4		
	Low	76.9	12.7	52.4	65.4	99.0		
Alta fescue 25%, Ladino clover 75%	Average	75.2	22.9	64.8	73.3	109.6	14.5	61.5
	High	77.3	32.0	67.1	75.4	122.7		
	Low	72.9	12.3	60.5	71.1	98.4		

percentage was directly related to the crude fiber percentage. The correlation between the crude fiber and the lignin of these grasses was .84. A change of 0.2646 units of lignin was associated with one unit change in crude fiber. This relationship suggests that the lignin content of these grasses may be used as an index of quality similar to crude fiber.

This group of grasses was high in ether extract, and the grasses were also palatable. It is possible that the relatively high ether extract, along with high protein content, contributed to this palatability. The calcium and phosphorus content of the grasses was relatively high except for the western wheatgrass and the mature crested wheatgrass.

The digestibility of the grasses is presented in table 3.

On the average, the digestibility of crude fiber in the grasses ranged from 41.8 percent to 79.3 percent with the more mature forage being less digestible. Coastal Bermuda and alfalfa gave a low coefficient of 41.8 percent for fiber digestibility. This low digestion coefficient was unexpected. It may be partially explained by the fact that the sheep did not readily eat the chopped mixture. The irrigated pasture mixture composed of half Alta fescue and half Ladino clover was 7 and 9 percent less digestible than the other two Alta fescue-Ladino mixtures. These two mixtures showed a rather high crude fiber digestibility of 64 to 66 percent which is associated with immature plants. The very immature crested wheatgrass, with a crude fiber content of 19.8 percent, had a very high digestibility of 79.3 percent. Immature grass is sometimes referred to as watered concentrate. This crested wheatgrass contains over three-fourths as much total digestible nutrients as that of some of the grains, and may be an example of watered concentrate; however, this grass contains much more crude fiber than is usually found in a concentrate.

Average digestion coefficients of the crude protein were found to range from 30 to 78 percent, with a mature forage having the lower digestibility. The immature crested wheatgrass had a protein digestion coefficient of 84 percent, which is greater than Kentucky fescue with 80 percent (Forbes and Garrigus, 1950).

There was a rather wide range of average digestion coefficients for ether extract. This variation may be due to the fact that there was a constant level of metabolic fat excretion in the feces regardless of the fat intake in the diet. Accordingly, when the intake of ether extract is low, its apparent digestibility may be lowered because of the disproportionate amount recovered in the feces. In these trials, decreases in ether extract content of the ration were accompanied by decreases in digestibility.

The average digestion coefficients for nitrogen-free extract ranged from 51 to 81 percent. This high coefficient of 81 percent is for the immature crested wheatgrass and is in agreement with a value of 80 presented for Kentucky 31 fescue by Forbes and Garrigus (1950).

According to Ellis *et al.* (1946), lignin is completely indigestible. Hence a lignin recovery of 100 percent can be anticipated. The range for lignin recovery runs from 81 to 109 percent. The lignin recovery observed for the two crested wheatgrasses did not seem to follow this pattern. The lignin for the two immature grasses was not completely recovered in the feces. The lignin recoveries for two immature grasses, tobosa and mesa dropseed, which are presented by Watkins (1955) were 77.7 and 76.6 percent, respectively. This raises a question as to the reliability of the use of lignin as an indicator in studying the digestibility of these grasses, especially when they are immature.

The total digestible nutrient percentages of the grasses, with only a few exceptions, were rather high. They ranged from 46 percent for the mature western wheatgrass (Trial 6) to 71 percent for the very immature crested wheatgrass (Trial 23). The crested wheatgrass in Trial 19 contained 51 percent old growth, but it still was quite palatable, and contained 48 percent total digestible nutrients. The coastal Bermuda and the Alta fescue-adino clover mixtures produced very high digestible nutrients which ranged from 56.8 to 61.5 percent. The sheep did not eat the chopped coastal Bermuda-alfalfa mixture readily. This lack of palatability and the low feed intake probably account for the low total digestible nutrients of 48 percent, since the coastal Bermuda-alfalfa mixture was superior in chemical composition to the coastal Bermuda grass by itself.

These grasses, when harvested at immature stages of growth, furnish a nutritious palatable forage very high in total digestible nutrients. The native range grasses, although producing less total digestible nutrients than these grasses reported on, produce their forage with much less precipitation.

There are several favorable factors bearing on the digestibility of roughage by sheep. Cipolloni *et al.* (1951) report the protein of low protein forages to be better digested by sheep than by cattle. This observation was earlier reported by Forbes (1937). Raymond *et al* (1954) report a trend showing that as sheep grow older they increase their ability to digest certain roughages. The average rise in digestibility found was about one unit for each year's increase in the age of sheep up to 36 months. The data of Raymond also indicate a seasonal trend in digestive

TABLE 4. BLOOD PLASMA, ANALYSIS, NITROGEN, CALCIUM, AND PHOSPHORUS AND RELATED DATA

	Wether No.	Grass [a] eaten	Balances			Plasma		
			Nitrogen	Calcium	Phosphorus	Vitamin A	Calcium	Inorganic Phosphorus
		lbs.	gm.	gm.	gm.	mcg./100 ml.	mg./100 ml.	mg./100 ml.
Western wheatgrass	6	2.9	—10.1	+ 6.8	+ 4.0	11.7	12.0	5.6
5.1 mg. carotene per lb.	5	2.4	— 3.1	+19.0	+ 6.9	15.4	14.7	5.4
	10	2.4	— 5.5	+12.2	+ 6.1	18.6	11.7	4.7
	11	2.1	— 4.7	+17.4	+ 9.0	16.3	11.5	5.2
Crested wheatgrass immature	1	2.4	— 0.4	+50.1	+25.9			
96.2 mg. carotene per lb.	2	2.3	—12.4	+11.2	+ 4.2			
	4	2.4	+13.2	+ 7.0	+ 2.6			
	7	2.3	— 5.0	+ 6.2	+ 0.5			
Crested wheatgrass	1	2.8	+13.7	— 5.7	+ 1.0	37.3	14.3	4.1
new and old growth	2	2.5	+ 2.9	— 4.4	+ 0.6	55.9	15.6	5.5
9.5 mg. carotene per lb.	6	1.9	+ 3.4	—10.3	— 2.1	30.3	12.2	5.1
	7	2.9	+11.0	— 4.1	+ 0.8	18.6	12.7	4.7
Coastal Bermuda grass	1	2.6	+30.2	+ 4.1	+ 8.5	32.6	12.7	5.3
35.2 mg. carotene per lb.	2	2.4	+27.9	—16.8	— 2.3	30.3	12.6	5.0
	4	2.0	+23.3	— 9.3	+ 2.6	16.3	11.1	5.0
	7	2.6	+23.8	—10.7	— 0.6	25.6	10.4	4.3
Coastal Bermuda grass 50%	1	2.0	—37.2	+14.7	— 4.5	53.6	12.1	5.2
Alfalfa 50%	2	2.1	—36.2	+10.9	— 7.1	51.3	13.5	4.6
34.7 mg. carotene per lb.	4	1.5	—27.8	— 7.2	— 5.3	32.6	12.7	4.6
	7	2.3	—31.1	+15.6	— 3.9	....	12.2	6.0
Alta fescue 75%	1	3.0	+50.0	— 0.2	+ 4.6	25.6	14.4	7.0
Ladino clover 25%	2	3.1	+56.6	— 8.7	+ 2.5	33.8	14.7	7.2
11.6 mg. carotene per lb.	6	2.1	+30.4	— 9.2	+23.5	28.0	15.7	7.5
	8	2.0	+40.3	— 0.9	+24.5	28.0	16.3	6.5
Alta fesclue 50%	1	3.4	+92.0	— 2.7	+11.0	14.7	13.5	5.7
Ladino clover 50%	2	3.1	+86.1	+39.9	+ 7.3	28.4	12.7	6.4
10.2 mg. carotene per lb.	6	2.0	— 6.0	+ 2.4	+ 0.5	25.6	13.0	7.3
	8	2.1	+60.2	+18.4	+ 4.4	28.9	12.8	7.6
Alta fescue 25%	1	3.6	+80.1	+26.1	+ 3.3	18.6	13.9	5.7
Ladino clover 75%	2	3.6	+77.2	+21.4	+ 4.1	29.4	13.6	5.6
8.7 mg. carotene per lb.	6	2.4	+25.1	+10.8	+ 5.3	16.3	13.1	5.6
	8	2.4	+26.8	— 5.3	— 3.1	24.7	13.7	6.2

[a] All grasses were cured and fed as hay in an air dry condition.

ability, with a fall during the winter followed by an increase in summer. It is possible that the rather favorable total digestible nutrient value found in this study may be due in part to some of these differences in digestive ability.

Various data assembled during the project are presented in table 4. A negative calcium balance was obtained with crested wheatgrass, old and new growth. This may be explained by a rather low calcium content of the grass. The same is true of coastal Bermuda. A large negative nitrogen balance was obtained for the wethers being fed the mixture of coastal Bermuda and alfalfa. The chopped hay mixture was unpalatable and was one of the factors causing the irregular feed intake. This irregular feed intake was possibly the principal factor in causing the negative nitrogen balances.

Summary

Eight metabolism trials were conducted with wethers to determine the relative feeding value of various grasses and grass-legume mixtures.

The mixed grasses, with only one exception, were high in feeding value as shown by chemical analyses, digestion coefficients, and total digestible nutrients.

The lignin content of these grasses was closely correlated with the crude fiber content, and in a similar way was an index of the quality of the roughage.

The various grasses included in this study, when grown under conditions of adaptibility, produced a good yield of palatable forage high in total digestible nutrients.

Literature Cited

Association of Official Agricultural Chemists. 1950. Official and Tentative Methods of Analysis. 7th edition.

Bell, W. B. and J. H. Britton. 1939. Losses of lambs and cattle on Ladino clover pastures. Mimeo. College Agr. Univ. Calif.

Cipolloni, Mary Ann, Burch H. Schneider, Henry L. Lucas and Helen M. Pavech. 1951. Significance of the differences in digestibility of feeds by cattle and sheep. JOURNAL OF ANIMAL SCIENCE 10:337.

Cook, C. W., L. A. Stoddart and L. E. Harris. 1954. The nutritive value of winter range plants in the Great Basin. Utah Agr. Exp. Sta. Bul. 372.

Ellis, G. H., G. Matrone and L. A. Maynard. 1946. A 72% H_2SO_4 method for the determination of lignin and its use in animal nutrition studies. JOURNAL OF ANIMAL SCIENCE 5:285.

Fiske, C. H. and Y. Subbarow. 1925. The colormetric determination of phosphorus. Jour. Biol. Chem. 66:375.

Forbes, E. B., J. W. Bratzler, A. Black and W. W. Braman. 1937. The digestibility of rations by cattle and sheep. Pa. Agr. Exp. Sta. Bul. 339.

Forbes, R. M. and W. P. Garrigus. 1950. Some effects of forage composition on its nutritive value when cut and fed green, as determined conventionally and by lignin ratio. JOURNAL OF ANIMAL SCIENCE 9:531.

Forbes, R. M. and W. P. Garrigus. 1950a. Some relationships between chemical composition, nutritive value, and intake of forages grazed by steers and wethers. JOURNAL OF ANIMAL SCIENCE 9:354.

Hawk, Philip B., Bernard L. Oser and William H. Summerson. 1937. Practical Physiological Chemistry. 12th edition. P. 579. The Blakiston Co., Philadelphia.

McCall, Ralph, R. T. Clark and A. R. Patton. 1943. The apparent digestibility and nutritive value of several native and introduced grasses. Montana Agr. Exp. Sta. Tech. Bul. 418.

Moore, L. A. 1939. Determination of carotene and vitamin A in blood. Jour. Dairy Sci. 22:501.

Morrison, F. B. 1948. Feeds and Feeding. 21st edition. Morrison Publishing Co., Ithaca, N. Y.

Raymond, W. F., C. E. Harris and C. D. Kemp. 1954. Studies in the digestibility of herbage. V. The variation with age, of the ability of sheep to digest herbage, with observations on the effect of season on digestive ability. Jour. of the British Grassland Society 9:209.

Swift, R. W., R. L. Cowan, G. P. Barron, K. H. Maddy, E. C. Grose and J. B. Washko. 1952. Further determinations of the nutritive value of forages. JOURNAL OF ANIMAL SCIENCE 11:389.

Thompson, C. R. and E. M. Bickoff. 1951. Proposed modification of the A.O.A.C. method of carotene in alfalfa. Assn. Offic. Agr. Chem. Jour. 34:219.

Walker, D. M. and W. R. Hepburn. 1955. The nutritive value of roughages for sheep. Jour. Agr. Sci. 45:298.

Watkins, W. E. 1955. Digestibility of range grasses and grass-legume mixtures New Mex. Agr. Exp. Sta. Bul. 400.

GRASS SILAGE PRESERVATION WITH SODIUM METABISULFITE [1]

J. W. Bratzler, R. L. Cowan and R. W. Swift [2]

The Pennsylvania State University

THE increased emphasis during recent years of the fundamental importance of grassland farming in our national system of agriculture has resulted in a keen interest in the problem of the preservation of forage crops for feeding livestock during winter months or when pasture is not available. The process of ensiling is particularly applicable for the earlier cuttings of forages as they usually are ready for cutting at a time when unsettled weather makes the field curing of hay difficult. Under ideal conditions with respect to stage of maturity and chemical composition of the grass, moisture content, efficient packing in the silo, and exclusion of air, good silage may be produced without preservative. The losses during fermentation, however, are always appreciable and often excessive and the odor is usually highly objectionable. In an attempt to wilt the crop before ensiling, the farmer is dependent on weather which may cause a delay in the date of cutting or which may result in leaching of the cut forage in the field.

This paper reports the results of two years of work with the use of sodium metabisulfite as a preservative which has given exceedingly satisfactory results in preserving the original nutrients in forages, resulting in highly palatable silages made by a process which requires no wilting and is therefore relatively independent of weather conditions at the time of harvest. The absence of unpleasant odor in silage preserved in this manner has been influential in causing many farmers to embark on a grass silage program who had previously been reluctant to do so. The serious problem of odor has long been recognized (Archibald, 1954).

The successful use of sulfur dioxide gas in grass silage as reported by Knodt (1950), by Knodt *et al.* (1952) and by Skaggs and Knodt (1952), implied that good results might be obtained with sodium

[1] Authorized for publication on June 14, 1955, as paper No. 1988 in the Journal Series of the Pennsylvania Agr. Exp. Sta., University Park.

[2] The research presented in this report was supported in part by grants from the Monsanto Chemical Company and from the General Chemical Division of the Allied Chemical and Dye Corporation, and from New Holland Division of the Sperry Corporation.

metabisulfite. The potential advantage of this preservative was indicated by the fact that it was a free-flowing powder, cheap, easy and safe to handle, and marketed in paper bags similar to those used for commercial fertilizers. Encouraging preliminary results were reported by Cowan *et al.* (1952, 1953). This was followed by more work with additional forages (Bratzler *et al.* 1955) and by extensive observations on many of the more than 7,000 silos filled with grass silage preserved with sodium metabisulfite in Pennsylvania during 1954.

First Year Studies

On May 27, 1952 three wood stave silos (5 x 24 feet) were filled with chopped orchard grass that was harvested just after heading (20–24 percent dry matter). One silo was treated with 8 lb. of bisulfite per ton of fresh grass, one received 80 lb. of molasses per ton, and the third received no preservative. The materials placed in each silo were carefully weighed, and samples of fresh grass from each load were dried in an oven for chemical analysis. In addition, a sufficient quantity of the fresh grass was dried artificially with forced-draft at 180° F. to permit the determination of its nutritive value, to compare it with the nutritive values of the silages. Each silo was well tramped between loads, and after filling was fitted with a plank cover and weighted with 50 gallons of water in a steel drum.

A careful accounting was made of the quantities of silage removed when these silos were opened. Beginning September 17, 1952, these silages were fed to sheep to determine the digestibility of the nutrients of each silage. Nine sheep, divided into groups of four and five, served as experimental subjects for these digestion trials. Each experimental period consisted of an 11-day preliminary feeding period during which the sheep were kept in individual metabolism cages and fed at the rate of 6.5 lb. of the fresh silage or 1.7 lb. of the dried grass per 100 lb. live weight per day. The animals were maintained on this same feed intake for an additional 10-day collection period during which time the feces and urine were collected separately and quantitatively from each animal each day. Methane was computed from the digestible carbohydrates of each ration by the formula of Swift *et al.* (1948). Either four or five sheep constituted a unit for the testing of each individual forage.

Four additional wood stave silos (5 x 20 feet) were filled on June 6 and 7, 1952 with a mixture of alfalfa and brome grass which was harvested when the alfalfa was in the bud stage (18 percent dry

matter). The silages were treated as follows: (a) 7.5 lb. bisulfite per ton of fresh forage, (b) 10.5 lb. bisulfite per ton, (c) 70 lb. molasses per ton and (d) no preservative. A sufficient quantity of the fresh forage for a digestion trial was dried artificially in the same manner as was followed with the orchard grass. These silos were opened on October 30, 1952, and the silages were evaluated by chemical analyses and by metabolism trials with sheep, using the same procedure as described above for the orchard grass silages.

Three concrete silos (3 x 8 feet) were filled with finely chopped third cutting practically pure alfalfa at about 10 percent bloom stage (23.0 percent dry matter) on September 9, 1952. The treatments were as follows: (a) 9.4 lb. bisulfite per ton of fresh forage, (b) no preservative, and (c) 36.4 lb. bisulfite per ton. The first two of these silos were filled for the purpose of determining the effectiveness of bisulfite in preserving the nutrients in a pure legume crop, as the spring trials had not included such a test. The third silo was filled to observe the effects of gross over-treatment with bisulfite. The first two silos were opened on March 30, 1953, and the silage fed to sheep in digestion trials as described above. Silage from the third silo (36.4 lb. bisulfite per ton) was fed to 4 dairy calves (300 lb. each) from February 6 to March 2. This silage was bright yellow in color, smelled strongly of sulfur dioxide, and was definitely lacking in palatability. However, there was no sign of digestive upset and when returned to the feed lot, the animals quickly returned to normal feed consumption.

Two 10 x 30 feet wood stave silos were filled June 5–9, 1952, with chopped alfalfa at a prebloom stage. One silo was treated with bisulfite at the rate of 8 lb. per ton of green forage, and the other with sulfur dioxide gas at the rate of 5 lb. per ton. These silages were fed, starting November 1, 1952, to dairy heifers of the Department of Dairy Science. The bisulfite treated silage was superior in color and odor, being uniformly olive-green in color throughout, while the sulfur dioxide treated silage had bleached areas at the injection sites and dark brown, strong smelling silage between these areas. In free-choice palatability trials, details of which are reported elsewhere (Bratzler *et al.*, 1955) the dairy heifers consumed an average of 58 lb. daily of the bisulfite treated silage and only 16 lb. of the sulfur dioxide silage. The bisulfite silage was preferred to about the same degree (63 lb. to 18 lb.) over excellent quality silage made from first

cutting alfalfa in airtight, glass-lined silos, which was hauled in from another farm for palatability comparisons.

Discussion of Results

Lack of space does not permit exhibition of all the data on this series of studies which may be found elsewhere (Bratzler *et al.*, 1955).

TABLE 1. COMPOSITION OF THE DRY MATTER OF EXPERIMENTAL FORAGES, 1952

	Crude protein	Ether extract	Crude fiber	Ash	N-free extract	Energy	Carotene
	%	%	%	%	%	Cal. per Kg.	mg. per lb.
Orchard grass							
Fresh forage	11.1	3.3	33.5	6.8	45.3	4497	
8 lb. bisulfite per ton [a]	11.1	4.4	33.5	7.7	43.3	4396	108.5
Fresh forage	10.9	3.3	34.2	6.8	44.8	4355	
No preservative [a]	11.1	3.9	36.4	6.8	41.8	4480	68.2
Fresh forage	11.0	2.9	34.6	6.6	44.8	4498	
80 lb. molasses per ton [a]	10.4	3.8	32.2	7.0	46.6	4360	80.8
Hay (artificially dried)	10.8	2.9	34.2	7.0	45.2	4422	7.7
Alfalfa-brome							
Fresh forage	17.1	2.7	30.4	9.5	40.3	4430	.....
7.5 lb. bisulfite per ton [a]	14.1	3.9	29.8	9.0	43.2	4456	91.6
10.5 lb. bisulfite per ton [a]	14.7	4.6	28.5	8.7	43.5	4342	120.2
No preservative [a]	16.1	4.8	33.2	7.5	38.4	4564	83.6
70 lb. molasses per ton [a]	12.5	3.6	28.3	7.8	47.8	4447	90.3
Hay (artificially dried)	15.9	2.9	31.5	8.6	41.2	4421	18.5
Alfalfa							
Fresh forage	22.0	3.1	23.4	8.6	44.1	4412	
9 lb. bisulfite per ton [a]	20.6	4.2	25.8	10.3	39.2	4418	
No preservative [a]	22.2	3.5	26.8	9.6	37.9	4570	
Hay (artificially dried)	21.6	3.0	24.3	8.3	42.9	4481	

[a] Silage.

All of the silages (orchard grass, alfalfa-brome and alfalfa) which had been preserved with sodium metabisulfite were markedly superior in color and odor to both the molasses treated and the no-preservative silages.

So far as the composition of the final product is concerned (table 1), the bisulfite silages were highest in carotene and it is also apparent

TABLE 2. DIGESTION COEFFICIENTS, TDN VALUES AND METABOLIZABLE ENERGY OF EXPERIMENTAL FORAGES 1952

	Animals	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Energy	TDN	Metabolizable energy
	No.	%	%	%	%	%	%	lb. per 100 lb. dry matter	Cal. per Kg. dry matter
Orchard grass									
8 lb. bisulfite per ton	4	66.5	61.7	63.0	73.5	63.8	63.2	65.4	2215
No preservative	4	64.8	57.9	60.6	75.1	59.6	61.8	64.2	2217
80 lb. molasses per ton	4	68.4	60.4	61.5	75.1	68.4	64.8	67.5	2288
Hay (artificially dried)	5	68.1	63.4	49.0	75.1	67.7	64.6	66.3	2281
Alfalfa brome									
7.5 lb. bisulfite per ton	5	71.3	70.1	64.6	71.1	73.7	68.2	68.6	2412
10.5 lb. bisulfite per ton	4	69.0	71.6	66.2	68.0	70.9	65.4	66.8	2253
No preservative	5	65.5	69.6	66.2	68.2	64.2	62.8	62.1	2186
70 lb. molasses per ton	4	71.9	64.4	66.3	72.1	75.7	68.6	70.0	2445
Hay (artificially dried)	4	65.4	68.9	43.5	66.7	66.4	62.1	62.1	2424
Alfalfa									
9 lb. bisulfite per ton	5	64.8	78.0	57.8	48.9	72.1	62.8	62.3	
No preservative	4	63.3	79.4	47.8	45.5	70.5	62.8	60.3	
Hay (artificially dried)	4	67.0	79.7	33.8	49.7	77.7	66.1	64.8	
Least significant									
difference between	4	1.5	2.7				1.6	1.2	70
means (Odds 19 to 1)	5	1.4	2.4				1.4	1.1	63

that considerably less sugars were lost due to fermentation from the bisulfite-treated silages than from the no-preservative or the molasses silages (if the large amount of N-free extract added in the molasses is taken into account).

With regard to the nutritive values of these silages (table 2), the data show no outstanding differences although the no-preservative silages were usually lowest in digestible energy, total digestible nutrients, and metabolizable energy. In every case the bisulfite silage was superior to the corresponding no-preservative silage with regard to

TABLE 3. LOSSES OF NUTRIENTS FROM EXPERIMENTAL SILOS FILLED WITH UNWILTED FORAGE, 1952

	Dry matter	Crude protein	Ether extract	Ash	Total carbohydrate	Energy	TDN
	%	%	%	%	%	%	%
Orchard grass							
8 lb. bisulfite per ton	8.9	7.4	—25.2	14.6	9.8	9.0	8.2
No preservative	11.3	9.6	— 4.2	11.6	12.1	8.7	14.1
80 lb. molasses per ton	21.7	21.7	—10.7	23.2	22.7	27.3	22.3
Alfalfa brome							
7.5 lb. bisulfiite per ton	12.3	26.3	—27.0	26.8	8.1	10.0	1.2
10.5 lb. bisulfite per ton	7.6	18.6	—58.2	28.4	3.1	6.8	— 2.3
No preservative	30.6	34.7	—21.5	45.3	29.6	28.2	30.6
70 lb. molasses per ton	17.5	33.0	—25.9	34.5	13.4	14.5	11.3
Alfalfa							
9 lb. bisulfite per ton	14.8	18.4	—17.4	11.6	14.9	12.9	16.5
No preservative	28.4	27.4	19.9	20.5	30.2	25.8	33.4

digestible dry matter and total digestible nutrients. The orchard grass-bisulfite silage also contained significantly more digestible protein, and the alfalfa-brome-bisulfite silages contained more digestible energy than the corresponding no-preservative silages.

The losses shown in table 3 represent the sum of the losses from seepage and from fermentation. Records were kept of the fresh weight of everything entering the silo and of all portions removed, moisture content being determined on all items. In the case of the orchard grass silage the treatment with bisulfite reduced the loss of carbohydrate (crude fiber plus nitrogen-free extract) from 12.1 to 9.8 percent. The loss from the untreated orchard grass (ensiled under nearly ideal conditions) was so low that the saving of nutrients due to treat-

ment was small, and in this particular case the improvement in odor, carotene value, and palatability of the bisulfite silage would have to be given some economic value in order to justify the cost of adding the preservative.

With the alfalfa-brome silages, however, the carbohydrate loss with 7.5 lb. bisulfite per ton was 8.1 percent; with 10.5 lb. bisulfite, 3.1 percent while the carbohydrate loss from the no-preservative silage was 29.6 percent. Similarly, with the alfalfa silages, treatment with bisulfite reduced the carbohydrate loss from 30.2 percent to 14.9 percent. The nutrients thus saved with both of these crops represent a cash value much more than sufficient to pay the cost of adding the preservative. Economic considerations are discussed in more detail elsewhere (Bratzler *et al.*, 1955).

The composition of the dry matter of the two artificially dried hays, of the silages (table 1) and the percentage digestibility of the various feed components, TDN and metabolizable energy values (table 2) pertain to the forages as fed. They afford no measure of losses which occurred during preservation. In order to evaluate these preservation treatments it is necessary to consider not only the composition and digestibility of the final product but also the losses which occurred prior to the chemical analysis and feeding of the silages (table 3).

A loss in a single component of a feed raises the percentage of all its remaining ingredients. This simple fact is ignored when the composition of the final product is used as a sole criterion of efficacy of procedures involved in preservation. For instance, the protein content of the no-preservative silages (table 1) is equal or superior to that found in the companion silages preserved with sodium metabisulfite or molasses. The reason for the higher protein content is apparent when the large carbohydrate losses (chiefly N-free extract) (table 3) of the no-preservative silages are taken into account. A silage may lose 30 percent or more of its protein and still contain a higher percentage of this nutrient at the end of the storage period than at the beginning, due to large losses of carbohydrate.

Second Year Studies

On July 30 and 31, 1953, finely chopped, unwilted second cutting red clover in medium bloom was ensiled in small wood stave silos as follows: In 5 x 20 feet silos, capacity 5–6 tons; (a) No preservative at 28.4 percent dry matter, (b) 7 lb. bisulfite per ton at 28.1 percent dry matter; in 5 x 10 feet silos, capacity 1.5–2 tons; (a) No preservative

at 31.6 percent dry matter, (b) 112 lb. molasses per ton at 33.2 percent dry matter.

A sufficient quantity of the fresh forage for a digestion trial with 4 sheep was packed in 100 lb. lard cans and frozen, to be held at 0° F. until fed.

Also on July 31, two 5 x 24 feet wood stave silos were filled with second crop red clover-alfalfa mixture harvested at an early bloom stage (about 20 percent dry matter). Dried beet pulp was added to the forage in both silos at rates of 77 and 92 lb. per ton, for the

TABLE 4. COMPOSITION OF THE DRY MATTER OF EXPERIMENTAL FORAGES, 1953

Forage	Treatment	Crude protein	Ether extract	Crude fiber	Ash	N-free extract	Energy
		%	%	%	%	%	Cal. per Kg.
Red clover 2nd crop medium bloom 5′ × 20′ silos	No preservative	18.0	4.6	26.4	7.2	43.8	4524
	7 lb. bisulfite per ton	16.5	3.8	26.5	6.9	46.3	4471
Red clover 2nd crop medium bloom 5′ × 10′ silos	No preservative	17.2	3.8	27.1	5.9	46.0	4440
	112 lb. molasses per ton	15.4	3.1	22.8	6.5	52.2	4292
Red clover 2nd crop medium bloom	Fresh frozen	17.2	3.0	24.4	6.2	49.3	4475
Red clover-alfalfa 2nd crop early bloom 5′ × 24′ silos	77 lb. dried beet pulp per ton	15.7	3.9	28.7	5.8	46.0	4529
	92 lb. dried beet pulp + 11 lb. bisulfite per ton	16.4	3.6	26.5	7.1	46.5	4475
Alfalfa-first crop medium bloom glass-lined silos	No preservative	16.5	4.5	35.4	7.5	36.1	4642
	8 lb. bisulfite per ton	16.3	4.3	35.8	7.2	36.4	4518

purpose of absorbing moisture and reducing seepage losses from the silos. The silo receiving 92 lb. of beet pulp per ton was also treated with bisulfite at the rate of 11 lb. per ton of forage. It was felt that, if seepage loss could be eliminated, and fermentation loss reduced by this combination of additives, the most serious disadvantages to the ensiling of immature, wet crops could be overcome.

As in the 1952 trials, the materials ensiled were carefully weighed, and samples of the fresh forages dried for chemical analysis. Each silo was well tramped between loads, and after filling was completed a 4-inch layer of limestone screenings was placed on the top, for the

TABLE 5. DIGESTION COEFFICIENTS, TDN VALUES, AND METABOLIZABLE ENERGY OF EXPERIMENTAL FORAGES, 1953

Forage and silo	Treatment	Sheep	Dry matter	Crude prot.	Ether ext.	Crude fiber	N-free ext.	Energy	TDN	Metabolizable energy
		No.	%	%	%	%	%	%	lb. per 100 lb. D.M.	Cal. per Kg. D.M.
Red clover 2nd crop medium bloom 5′ × 20′ silos	No preservative	5	63.9	65.8	70.9	50.4	72.0	61.9	64.0	2372
	7 lb. bisulfite per ton	5	63.8	62.9	67.0	53.2	72.1	61.0	63.6	2294
Red clover 2nd crop medium bloom 5′ × 10′ silos	No preservative	4	59.5	58.9	64.5	46.6	70.0	56.6	60.5	2065
	112 lb. molasses per ton	6	65.7	59.3	64.3	49.6	76.5	61.7	64.9	2237
Red clover 2nd crop medium bloom	Fresh frozen	4	64.5	65.4	52.5	48.0	75.7	62.3	63.8	2318
	Fresh frozen + 112 lb. molasses per ton	4	68.0	63.6	50.4	46.0	80.0	64.6	66.6	2330
Red clover-alfalfa 2nd crop early bloom 5′ × 24′ silos	77 lb. dried beet pulp per ton	5	65.4	63.6	63.0	57.7	74.0	63.1	66.1	2378
	92 lb. dried beet pulp + 11 lb. bisulfite per ton	5	67.5	66.3	65.6	60.2	74.9	65.4	66.9	2476
Alfalfa 1st crop medium bloom glass-lined silos	No preservative	5	56.6	60.2	67.4	49.5	62.6	53.7	56.4	2079
	8 lb. bisulfite per ton	5	58.2	64.2	58.3	52.9	62.7	54.0	57.9	2010
Least significant difference between means (Odds 19 to 1)		4	1.5	2.7				1.6	1.2	70
		5	1.4	2.4				1.4	1.1	63

purpose of compacting and sealing the top layer. No additional weight was added. The composition of the silages and of the original red clover crop is shown in table 4. The two forages, preserved as above, were evaluated by means of digestion and metabolism trials with sheep. Essentially the same procedure was followed in emptying the silos, and in conducting the sheep trials, as was used in the 1952 studies. The nutritive values as indicated in table 5 reveal no marked differences between the final products as fed.

Two glass-lined, air-tight silos at the University dairy barns were filled, starting June 18, with alternate loads of first cutting alfalfa at an early to medium bloom stage of maturity. One silo was treated with 8 lb. of bisulfite per ton of forage, and the other received no preservative. These silos were opened about November 19, and fed to dairy cows in the University milking herd. Both silages were apparently of good quality; however the bisulfite treated silage was definitely superior in color and odor, being entirely free of the clinging odor that was evident in the no-preservative silage (analysis showed 4 percent butyric acid in the no-preservative silage, and none in the bisulfite silage). In a palatability trial similar to that described in the 1952 report, one pen of yearling heifers consumed an average (per head) of 38 lb. of the bisulfite silage and only 10 lb. of the no-preservative silage daily. Another pen of smaller heifers consumed 30, and 7 lb. respectively of the same two silages.

Discussion of Results

Little (1954) has also reported the preference by heifers of bisulfite silage as compared to the same crop with no preservative, and that the treated silage was characterized by a pleasing odor. The chemical composition of the final products were about the same. As pointed out above, this gives no information regarding fermentation losses which may have occurred.

These silages (1953 crop) were all of good quality, and were readily eaten by both cattle and sheep (surpluses were fed by the Department of Dairy Science). Red clover, being rich in sugar and intermediate in protein content, would normally be expected to make good silage without preservative. The second cutting material used in this experiment was of exceptionally good quality and its stage of maturity and moisture content were nearly optimum at the time of ensiling. The bisulfite treated silage retained much more of the green color than those made by the other methods, which were quite dark.

TABLE 6. LOSSES OF NUTRIENTS FROM EXPERIMENTAL SILOS FILLED WITH UNWILTED FORAGE, 1953

Forage	Treatment	Dry matter	Crude protein	Ether extract	Ash	Total carbo-hydrate	Energy	Dig. energy	Metab. energy	TDN
		%	%	%	%	%	%	%	%	%
Red clover,	No preservative	26.7	24.8	—23.4	24.8	29.2	25.8	26.3	25.0	26.4
2nd crop, medium bloom,	7 lb. bisulfite per ton	3.0	6.1	—53.0	20.3	1.7	2.6	4.6	3.0	2.2
5′ × 20′ wood stave silos										
Red clover,	No preservative	21.8	22.6	—51.9	33.9	21.8	22.4	29.5	30.4	25.8
2nd crop, medium bloom,	112 lb. molasses per ton	20.2	19.9	— 4.9	20.7	20.7	20.7	24.2	23.8	22.2
5′ × 10′ wood stave silos										
Red clover-alfalfa,	77 lb. dried beet pulp per ton	31.6	39.0	—15.0	42.2	30.4	30.6			
2nd crop, early bloom.	92 lb. dried beet pulp + 11 lb.									
5′ × 24′ wood stave silos	bisulfite per ton	17.2	18.0	—31.5	25.2	17.1	15.3			

Its odor was also superior, resembling very closely that of the fresh-chopped clover. The other silages were not unpleasant in odor, but smelled "fermented" to varying degrees.

The losses of nutrients from these silages, determined in the manner described in the first year studies, are shown in table 6. It is apparent that treatment with bisulfite resulted in spectacular savings of nutrients, as shown by the difference in percentages of nutrients lost from the untreated and the bisulfite-treated silages. As in the case of the 1952 silages this saving appears to involve mostly the carbohydrate fraction of the forage (N-free extract and crude fiber) and may be explained on the basis of reduced fermentation of these constituents. Since this carbohydrate portion represents about 70–75 percent of the dry matter of the forage, and contributes most of the digestible energy of the feed, this saving is very important. It should be pointed out however that some carbohydrate may be converted to acids which have nutritive value. Such acids, however, would appear in the ether extract fraction. The percentage saving of crude protein was also great, but is of lesser importance since it represents a much smaller proportion of the dry matter of the forage. In the feeding of grass crops as a sole diet to dairy or beef animals, it is most often the content of disgestible energy, and not of protein, which becomes the limiting factor.

The addition of molasses and of dried beet pulp alone, while improving the quality of the silage to some extent (possibly by promoting "favorable" types of fermentation), did not serve to reduce losses of nutrients. The losses from both of the 5 x 10 feet silos (no preservative and molasses treated) were smaller than those from the same crop ensiled in 5 x 20 feet silos, possibly due to decreased seepage and/or fermentation caused by the combination of slightly higher dry matter content of the ensiled crop and decreased depth.

The higher moisture content of the forage ensiled with beet pulp, coupled with accelerated fermentation due to the addition of the beet pulp carbohydrate, may account for the large losses of nutrients from the silo which did not receive bisulfite. Here again, it is apparent that treatment with bisulfite has caused diminished fermentation losses. There was some seepage (unmeasured) from both of these silos, in spite of the added beet pulp.

The effectiveness of bisulfite in inhibiting fermentation in silage has been confirmed by the work of Alderman *et al.* (1955). He analyzed samples from 48 of the farm silos filled in the 1953 field trials

(described below) for the common fermentation products found in silage. The data show that production of acetic and lactic acids by bacterial fermentation was limited and inversely correlated with the total residual sulfite concentration in the silage. Butyric acid production was almost eliminated. Protein breakdown was also inhibited to a satisfactory degree, despite pH values higher than normal.

It is widely accepted that a low pH of the order of 3.5 to 4.5 is one of the chief criteria of a well preserved silage. The mean pH for all of these samples of bisulfite silages was 4.49, which barely falls within the desired range, and in fact 17 samples fell within the range 4.6–5.0. Alderman's individual data showed a number of silages with pH values of 4.8 and 4.9 were better preserved, as judged by the quantities of fermentation products formed, than silages with pH values within the accepted range. These results suggest that the forages were preserved primarily by the action of the bisulfite ion, instead of by the acidity or hydrogen ion as is usual in other conventional types of silages.

Archibald (1954), reporting on similar analysis, presents further evidence of the beneficial effect of bisulfite in limiting the fermentation of high moisture silage, and discusses in considerable detail the excellent quality of these silages.

Table 5 shows digestion coefficients, and metabolizable energy and total digestible nutrient (TDN) values for the 1953 experimental forages.

From these data, and from those reported on the 1952 silage, bisulfite reduces losses of the more digestible portions of the feed, resulting in generally more palatable, more nutritious silages.

These results have been substantially confirmed by Woolfolk *et al.* (1954) in feeding trials with pregnant-lactating ewes and in digestion trials with wethers in which they compared alfalfa silage preserved with molasses, sulfur dioxide gas, and sodium bisulfite. They report differences in digestibility in favor of the bisulfite silages over molasses and sulfur dioxide silages for dry matter, crude protein, crude fiber, N-free extract, and energy, which were highly significant in all cases except in the comparison of crude protein digestibility with sulfur dioxide silage. Differences in fleece weights, bodyweight losses, and weights of lambs were also in favor of the groups receiving bisulfite treated silage.

Summary

Evidence has been presented to show that sodium metabisulfite is a very satisfactory preservative for grass silage for the following reasons:

1. It can be applied easily and uniformly to the fresh forage.
2. It reduced drastically the losses due to fermentation.
3. Forage can be ensiled in the unwilted state.
4. Bisulfite silages were more palatable and nutritious than corresponding silages made from the same forages but without the addition of a preservative.
5. Bisulfite silages were virtually free of undesirable and unpleasant odors.

Literature Cited

Alderman, G., R. L. Cowan, J. W. Bratzler and R. W. Swift. 1955. Some chemical characteristics of grass and legume silage made with sodium metabisulfite. Jour. Dairy Sci. 38:805.

Archibald, J. G., M. L. Blaisdell, B. Gersten and D. M. Kinsman. 1954. Grass silage—A reappraisal. Mass. Agr. Exp. Sta. Bul. 477.

Archibald, J. G. and J. W. Kuzeski. 1954. Further observations on the composition of grass silage. Jour. Dairy Sci. 37:1283.

Bratzler, J. W., R. L. Cowan and R. W. Swift. 1955. Preservation of grass silage with sodium metabisulfite. Pa. Agr. Exp. Sta. Bul. 597.

Cowan, R. L., J. W. Bratzler and R. W. Swift. 1952. Use of sodium metabisulfite as a preservative for grass silage. Sci. 116:154.

Cowan, R. L., J. W. Bratzler and R. W. Swift. 1953. Grass silage preservation with sodium bisulfite. Pa. Agr. Exp. Sta. Progress Report 99.

Knodt, C. B. 1950. The sulfur dioxide preservation of grass silage. JOURNAL OF ANIMAL SCIENCE 9:540.

Knodt, C. B., S. R. Skaggs and P. S. Williams. 1952. Sulfur dioxide for preservation of forage. Pa. Agr. Exp. Sta. Bul. 552.

Little, C. J. 1954. The palatability of hay crop silage treated with sodium bisulfite. Mich. State College Agr. Exp. Sta. Quarterly Bul. 37.

Skaggs, S. R. and C. B. Knodt. 1952. Sulfur dioxide preservation of forage crops. Jour. Dairy Sci. 35:329.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The effect of dietary fat on utilization of the energy and protein of rations by sheep. JOURNAL OF ANIMAL SCIENCE 7:475.

Woolfolk, T. G., C. M. Thompson and R. B. Grainger. 1954. Alfalfa silage preserved by various methods for pregnant-lactating ewes. JOURNAL OF ANIMAL SCIENCE 13:1014.

THE EFFECTS OF INJECTED TESTOSTERONE ON ADULT EWES [1]

E. F. Johnston, Frank Hudson, Ralph Bogart, A. W. Oliver and Fred F. McKenzie

Animal Husbandry Department [2]

TESTOSTERONE is known to increase the rate and efficiency of gain in growing-fattening beef cattle. However, this increase of gain is accompanied by a marked masculine development in both sexes. The following experiment was set up to determine if the use of testosterone would have any effect on rate of gain and development of masculine traits in adult ewes.

Experimental

Six purebred Hampshire and two purebred Suffolk adult ewes varying considerably in age were divided into two groups of 3 Hampshire and 1 Suffolk each. One group was given testosterone while the other acted as control. All the ewes were culls from the breeding flock and were thin, but both groups were fed a good ration of grain and alfalfa during the experimental period.

The treated animals and the controls were kept together in a small enclosure and fed a fattening ration. They were given all the grain each day they would consume in about 10 minutes and they were given all the alfalfa hay they would eat. Water and a phenothiazine-salt mixture was provided. The grain consisted of a barley and oats mixture with the barley comprising about 80 percent of the grain ration. The animals were fed once a day.

Testosterone (Oreton F, Schering), injected twice weekly, at the rate of 50 mg., was used during the first seven weeks after which testosterone suspended in Mazola oil at the same dilution (50 mg. per ml.) and at the same dose (50 mg. per injection) was used. Injections were made into the leg muscle on the inside part of the rear leg. The four treated sheep were treated for eight weeks after which injections were discontinued on two of them.

All eight sheep were slaughtered at the end of the tenth week and

[1] Approved for publication as technical paper 913 by the Director of Oregon Agricultural Experiment Station.

[2] Corvallis, Oregon.

endocrine glands, kidneys and the liver were weighed and fixed for histological studies. The meat of both legs was ground and fed to young cockerels to test for retained hormone in the meat by measuring increase in comb size.

The sexual behavior of the sheep was noted during feeding (once a day) and at eight weeks and ten weeks of treatment by placing an estrous ewe with them. Movies were taken at these two times to record sexual behavior. Just before slaughter the clitoris of each ewe was photographed. Also, each ewe was photographed from a side view.

After the clitorides were removed, a photograph was taken of all of them so that a direct comparison could be made. Weights of the clitorides were taken.

Results

Effect of Treatment on Behavior

After the second week of treatment, the ewes receiving testosterone were manifesting male behavior. This behavior may have been present earlier and gone unnoticed, or it may be that no control ewe came into estrus before that time. This behavior consisted of wrinkling of the nose, pawing and stamping of the feet, fighting, and attempts to ride the animal in heat. This behavior became progressively more evident as the injections were continued. The Suffolk ewe, C61, showed such behavior first and to a greater degree than did any of the treated Hampshires. During the eighth week of treatment one ewe was observed in heat in the breeding flock. This ewe was brought to the shed where the experimental animals were kept, and the treated animals were placed with her one at a time. From a visual standpoint, the behavior of the treated ewes was typically masculine. They uttered sounds which were not distinguishable audibly from those made by a ram in the presence of a ewe in heat. Stamping, nose wrinkling, licking, and other imitations of male behavior were noted. When the treated ewes rode the one in heat, it appeared from visual inspection that the treated ewes experienced an orgasm. A thrust was made which was similar in all respects to that made by the male when ejaculating, and subsequently the treated ewes acted very much like a ram does after serving a ewe. They came off the ewe in heat and paid no further attention to her for a few minutes. The treated ewe then seemed to become interested again and went through the "courting" procedures and finally mounted and made another thrust.

Effect on Gross Appearance of Living Ewes

The ewes still looked like females when a cursory inspection was made. However, the "expression" of the face and particularly that of the eyes was markedly different in the treated ewes. The placid expression present in the control ewes had changed to an aggressive expression similar to that found in rams. The wool about the head seemed to stand out and to be individual fibers rather than hanging smoothly in locks. The wool on the poll was thinner in the treated ewes and was almost absent on one of them. This may, of course, have been caused mechanically by fighting or in other ways.

Effect on Clitorides

Photographs of the vulval area in the live animal are shown in figure 1. These photographs do not show clearly the effects of testosterone treatment on the clitorides. For this reason the clitorides were dissected out after slaughter, weighed, and photographed. The weights are presented in table 1.

Figure 1. Vulva spread showing clitoris of a control ewe (left) and a testosterone treated ewe (right).

The differences due to treatment are clearcut and highly significant. Clitorides of the sheep injected with testosterone for ten weeks were significantly heavier than those of sheep allowed to regress for two weeks following injections of testosterone for eight weeks. Clitorides of sheep treated eight weeks and allowed to regress were significantly heavier than those of controls. There may be some question as to whether the clitorides of D7 and A8 actually regressed or simply did not develop as much as those of B25 and C61. However, these organs were manually examined two weeks before slaughter and little difference in their sizes was found among the treated sheep. This indicates that

TABLE 1. WEIGHTS OF CLITORIDES FROM CONTROL EWES AND THOSE RECEIVING TESTOSTERONE FOR DIFFERENT PERIODS OF TIME

Group	Ewe number	Clitoris weight
		gm.
Testosterone-injected for 10 weeks	B25	1.90
	C61	1.70
Testosterone-injected for 8 weeks—none for 2 weeks	D7	0.88
	A8	0.91
Controls—no testosterone	Fox 28	0.32
	6445	0.31
	C1	0.33
	105	0.34

clitorides weights were approximately the same for the treated sheep two weeks before slaughter and that the discontinuance of treatment caused the clitorides of D7 and A8 to become smaller in size. The exised clitorides were photographed and are shown in figure 2.

Effect of Testosterone on Weights of Heart, Liver, and Kidneys

There were no significant effects of treatment on the weights of the livers or kidneys (table 2). The hearts of treated animals weighed significantly less than those of controls (table 2). One would expect

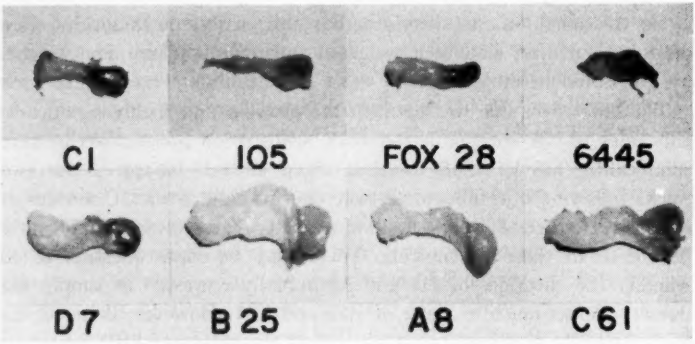


Figure 2. Excised clitorides of control ewes (top) and testosterone treated ewes (below).

TABLE 2. WEIGHTS OF ORGANS AND GAINS FROM CONTROL AND TESTOSTERONE-TREATED EWES

		Controls					Treated				
		C1	105	F28	45	Average	D7	B25	A8	C61	Average
Final weight in lb.		129	110	130	115	121	76	139	125	109	112.3
Gain, lb.		23	15	28	12	19.5	—3	23	30	17	16.8
Heart weight, gm.		301	280	285	273	285	234	269	264	230	249
Liver weight, gm.		990	950	954	846	935	640	1106	1012	636	849
Kidney weight, gm.	Right	67	79	81	78	76	48	80	72	54	64
	Left	63	77	80	76	74	50	86	75	63	69
Pituitary weight, gm.		1.40	1.40	1.70	1.31	1.45	.80	1.93	1.31	1.04	1.27
Thyroid weight, gm.		4.21	4.40	5.31	4.17	4.52	1.76	3.73	3.60	2.48	2.89
Adrenal weight, gm.	Right	2.00	2.60	3.74	3.98	3.08	1.61	2.13	3.42	2.41	2.39
	Left	2.40	2.55	3.56	3.90	3.10	1.87	2.13	3.15	2.23	2.35
Ovary weight, gm.	Right	1.28	1.00	1.01	1.80	1.27	.65	1.07	.87	1.57	1.04
	Left	1.60	1.34	1.21	.94	1.27	.54	1.24	1.32	1.45	1.14

testosterone to bring about increased activity which would increase the metabolic rate. Therefore, if there were any change at all in the size of the heart due to testosterone treatment, one would expect it to be an increase. The treated sheep weighed five pounds less on the average at the beginning of the experiment than the controls and 11 pounds less at slaughter. This may account for the difference in heart weights observed.

Effect on Pituitary

Weights of the pituitaries of treated animals were not significantly different from those of the controls (table 2).

Effect on Thyroid Weight

The thyroid glands of the testosterone treated animals (average weight of 2.67 gm.) were smaller (table 2) than those of the controls (average weight of 4.52 gm.). This difference is significant at the 5 percent level. Burris, Bogart and Krueger (1953) obtained results contrary to these in their experiments on beef animals. Thyroid glands were larger in the testosterone treated group and thyroid was correlated with an increased rate of gain.

The results of the present study show no increase in rate of gain from testosterone injections (table 2), and since thyroid sizes were smaller in the testosterone treated sheep than in the control sheep, it is suggested that the mode of action of testosterone in sheep is different from that in cattle. There is also the possibility that young animals such as the beef cattle used by Burris *et al.* (1953), react differently to injected testosterone from aged animals such as the sheep used in the present study.

Effect on Adrenals

There was no significant difference between the weights of the adrenals of treated animals and those of controls (table 2).

Effect on Ovaries

The weights of the ovaries of treated and untreated animals were not significantly different (table 2). However, there were marked differences in their appearance. Three of the control ewes had ovulated and corpora lutea were present. The other control ewe had not ovulated but had one large follicle in each ovary. None of the treated ewes had

ovulated, and their ovaries contained follicles which were very small and atretic. The ovaries of the treated ewes had a solid appearance and were firm to the touch as contrasted to the soft liquid consistency of the ovaries of the controls. The ovaries of the two ewes treated ten weeks appeared white and fibrous. Those of the other two treated ewes were less white and fibrous than ovaries of the ewes treated for ten weeks but more so than those of the controls.

Effect on Dressing Percentage

The treated ewes had a dressing percentage of 47. The average dressing percentage of control ewes was 44. The difference was not statistically significant. All the ewes were sheared the day before slaughter so that differences in fleece weights would not affect the dressing percentage.

Effects on Appearance of Carcass

In gross appearance of carcasses there were no consistent differences between treated and control groups. Market grades were the same for the three groups as determined by a state grader.

Results of Test for Residual Testosterone in the Meat

The meat of the ewes was ground and fed to cockerels for a period of 4 weeks beginning when the cockerels were 4 weeks old. There was no evidence of residual testosterone in the meat. The chicks fed meat from the control ewes had significantly greater comb growth than did those fed meat from the treated ewes. The procedures for the test are described and the results are discussed elsewhere (Johnston *et al.*, 1955).

Summary and Conclusions

1. Testosterone injected intramuscularly at the rate of 100 mg. per week in adult ewes had the following effects:

(a) Changed normal female behavior to typical male behavior,
(b) Significantly enlarged the clitorides,
(c) Significantly reduced the size of hearts,
(d) Significantly reduced the size of thyroid glands,
(e) Did not increase rate of gain of the ewes,
(f) Did not alter carcass grades.

2. The weights of livers, kidneys, adrenals, pituitaries, and ovaries apparently were not affected by the testosterone. However, the appearance and consistency of most of these organs were altered, indicating that there might be histological difference caused by the testosterone.

3. A chick assay indicated that there was no active residual testosterone in the meat of the treated ewes which were slaughtered 4 days after the last injection of testosterone.

4. Clitorides of ewes which were treated 8 weeks and then not treated for 17 days before slaughter had regressed but were still above the normal size.

Literature Cited

Burris, M. J., Ralph Bogart and Hugo Krueger. 1953. Alteration of activity of thyroid gland of beef cattle with testosterone. Proc. Soc. Exptl. Biol. Med. 84:181–183.

Johnston, E. F., Frank Hudson, Ralph Bogart and John Kaufmes. 1955. Retention of injected testosterone in the meat of adult ewes. Unpublished data.

RETENTION OF INJECTED TESTOSTERONE IN THE MEAT OF ADULT EWES [1]

E. F. JOHNSTON, FRANK HUDSON, RALPH BOGART AND JOHN KAUFMES

Oregon State College [2]

INJECTED testosterone in growing-fattening cattle (Burris *et al.*, 1953; 1954), male and female rabbits (Oloufa and Bogart, 1954) and adult ewes (Johnston *et al.*, 1955) has been shown to increase rate and efficiency of gain of cattle and rabbits. Before recommending this practice it is desirable to know whether there is any residual testosterone in the meat.

Oloufa and Bogart (1954) found no evidence of residual testosterone when meat from control and treated rabbits was fed to castrated male and female rats. The following report gives results of testing for residual testosterone in the meat of adult ewes.

Procedure

Eight adult ewes which for various reasons were culled from the experiment station breeding flock were fed a fattening ration of grain and alfalfa hay. Four of these ewes were injected with 100 mg. of testosterone (Oreton F. Schering) per week. Two of these treated ewes were injected for 10 weeks and were slaughtered on the fourth day after the last injection. The other two treated ewes were injected for 8 weeks and slaughtered 17 days after injections were discontinued. All treated and control ewes were slaughtered the same day.

The meat of the rear legs was ground and fed to cockerel chicks for a period of 4 weeks, starting when the chicks were 4 weeks of age. The chicks were fed a commercial ration *ad libitum* before and during the test period. The meat was fed at the rate of approximately 27 gm. per chick daily in addition to the regular ration. Weights of the chicks and the length and height of comb were obtained initially and at weekly intervals.

[1] This study was conducted in cooperation with Bureau of Animal Industry, U.S.D.A., and State Experiment Stations under Western Regional Project W-1 on Beef Cattle Breeding Research. Technical paper 916, Oregon Agricultural Experiment Station, Corvallis.

[2] Department of Animal Husbandry, Corvallis.

Results

Gains in weight among chicks fed the three kinds of meat were quite similar. Analysis was made by covariance to adjust the gain made and the increase in comb size for difference in initial weight and initial size of combs. Comb growth was less for chicks fed the meat from testosterone-treated ewes. Growth of combs was slightly less for the chicks fed the meat of the ewes treated for 10 weeks than for those fed the meat of the ewes treated for 8 weeks. Increase in height of combs of chicks fed the meat from control ewes was significantly greater than the increase in height of combs of chicks fed meat from the treated ewes (table 1).

TABLE 1. MEANS AND ADJUSTED MEANS FOR INCREASE IN WEIGHT, COMB HEIGHT AND COMB LENGTH OF CHICKS FED MEAT FROM CONTROL AND TESTOSTERONE TREATED EWES

	Weight increase, gm.		Comb height increase, mm.		Comb length increase, mm.	
Treatment	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Control	847.45	849.55	17.31	17.01	30.12	29.65
Testosterone, 8 weeks	843.65	837.85	15.25	15.32	28.00	27.86
Testosterone, 10 weeks	833.10	836.79	13.56	13.79	25.00	25.61
F	0.14	0.14	5.50*	4.99*	2.70	1.77
L.SD. (.05)			2.29	2.26		

* $P<0.05$.

Discussion

Turner (1948) found that any of several androgens administered orally to chicks increased the size of their combs over that of controls. Testosterone was most effective, followed by testosterone propionate, methyl testosterone, and transdehydro-(iso)-androsterone in that order. Testosterone increased the growth rate of the combs about 300 percent, testosterone propionate about 200 percent, and transdehydro-(iso)-androsterone about 60 percent over that of controls. Turner used crystalline materials and started his treatment when the chicks were 1 day old. It was not practical for us to use day-old chicks because of difficulties in getting them to eat the meat.

However, if there was any residual testosterone in the meat, an increased comb growth should have been obtained in the chicks fed the meat from the treated ewes. There is the possibility that some may have been present in a bound and ineffective form. The fact that the comb growth of chicks fed the treated meat was significantly less

than that of the controls was totally unexpected. Since the feeding of meat from beef animals injected with testosterone also led to a reduced comb growth (unpublished data) the validity of these findings is substantiated. Several possibilities are suggested, (1) that there is some metabolic product of the testosterone in the meat which inhibits comb growth, (2) that there may be an anti-hormone present, (3) that the systemic effect of the testosterone has been to change the composition of the meat and (4) that the testosterone may have increased estrogen production in these ewes, which might have the effect of decreasing comb growth in chicks eating meat from such treated animals.

Summary

Meat from control and testosterone treated ewes was fed to four-week-old cockerel chicks to determine whether there was any residual testosterone in the meat as evidenced by increases in chick weight and comb size.

There were no significant differences in body weight and comb length increases, but the increase in comb height was significantly greater for chicks fed meat from control ewes. These results indicate that there was no residual testosterone present in the meat of ewes 4 days after treatments ceased.

Literature Cited

Burris, M. J., Ralph Bogart and A. W. Oliver. 1953. Alteration of daily gain, feed efficiency, and carcass characteristics in beef cattle with male hormones. JOURNAL OF ANIMAL SCIENCE 12:740.

Burris, M. J., Ralph Bogart, A. W. Oliver, A. O. Mackey and J. E. Oldfield. 1954. Rate and efficiency of gains in beef cattle. I. The response to injected testosterone. Oregon Agr. Exp. Sta. Tech. Bul. 31.

Johnston, E. F., Frank Hudson, Ralph Bogart and A. W. Oliver. 1955. The effect of injected testosterone on adult ewes. (Unpublished.)

Oloufa, M. M. and Ralph Bogart. 1954. Retention of sex hormones in the meat of rabbits. Proc. West. Section Am. Soc. of An. Prod. 1954.

EFFECT OF CHLORTETRACYCLINE, STILBESTROL AND CHLORTETRACYCLINE-STILBESTROL SUPPLEMENTS ON FATTENING LAMBS [1]

P. S. JORDAN, R. M. JORDAN AND H. G. CROOM

University of Minnesota [2, 3]

RECENTLY Hale *et al.* (1954) reported significant growth stimulation with no lowering of carcass grade in lambs fed 1.8 mg. of stilbestrol daily. This work was confirmed by Bell and Erhart (1955) who obtained an increase in rate of gain with no lowering of carcass grade when 2 mg. of stilbestrol were fed per lamb daily. Conversely, Jordan *et al.* (1955) failed to obtain any increase in growth rate or feed efficiency when either 0.1, 0.5 or 1.5 mg. of stilbestrol were fed per lamb daily. Feeder lamb responses to antibiotics have been inconsistent. In a series of trials in which chlortetracycline (Aureomycin) was incorporated in a fattening ration, Jordan (1952) reported a slight improvement in growth rate in two trials, and a slower growth rate in three trials. Jordan and Bell (1954) obtained increases in growth rate in three of four trials with suckling lambs fed chlortetracycline. Hatfield *et al.* (1954) reported an average increase of 0.055 lb. per lamb daily and an improveemnt in carcass grade when chlortetracycline was added to lamb rations. Recently, for cattle, antibiotics and stilbestrol have been suggested as having greater growth stimulation when fed in combination than when fed separately. The following experiment was designed to obtain information on the effect of feeding to fattening lambs either chlortetracycline, stilbestrol or a combination of the two in rations of two concentrate-roughage ratios.

Experimental Procedure

Eighty lambs were randomly allotted into eight lots of 10 lambs each. They were sheared prior to being placed on experiment and hand-fed in an open shed with access to fresh water, salt, and equal parts of trace mineralized salt and bone meal. Two different concen-

[1] Paper No. 3377 Scientific Journal Series of the Minn. Agr. Exp. Sta., St. Paul.

[2] Stilbestrol feed supplement was donated by Eli Lilly and Company through the courtesy of Dr. J. F. Downing, and the chlortetracycline was donated by Lederle Laboratories through the courtesy of Dr. R. F. Elliot.

[3] This project was supported in part by Grants-In-Aid from Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York.

trate-roughage ratios were used and the various treatments superimposed on each ratio. One ration consisted of 45 percent concentrate and 55 percent roughage; the other one was 35 percent concentrate and 65 percent roughage. A tenth of a pound of soybean oil meal used as the carrier for the chlortetracycline and/or the stilbestrol, was fed per lamb daily to all lots. The rations fed per lamb, daily, were:

Concentrate-Roughage Ratio 45–55. Lot 1, basal ration consisting of 45 percent shelled corn, 55 percent long alfalfa hay and 0.1 lb. of soybean oil meal; Lot III, basal ration plus 21.6 mg. of chlortetracycline; Lot V, basal ration plus 21.6 mg. of chlortetracycline and 2 mg. of stilbestrol; Lot VII, basal ration plus 2 mg. of stilbestrol.

Concentrate-Roughage Ratio 35–65. Lot II, basal ration consisting of 35 percent shelled corn, 65 percent long alfalfa hay and 0.1 lb. of soybean oil meal; Lot IV, basal ration plus 21.6 mg. of chlortetracycline; Lot VI, basal ration plus 21.6 mg. of chlortetracycline and 2 mg. of stilbestrol; Lot VIII, basal ration plus 2 mg. of stilbestrol.

Records on growth, daily feed consumption and carcass grade and yield were obtained on all lambs slaughtered.

Results and Discussions

The results of the trial are presented in table 1.

Rate of Gain

At neither the 35–65 concentrate-roughage ratio or the 45–55 ratio did the addition of chlortetracycline, stilbestrol or a combination of the two significantly affect the rate of gain. However, at the higher concentrate level, the chlortetracycline-fed lambs gained slightly faster than the controls and at the lower concentrate level the rate of gain was slightly lower than the controls. Perry *et al.* (1954) reported that the proportion of concentrate to roughage in steer fattening rations has a real bearing on the results obtained with chlortetracycline and that best results are obtained when a relatively high proportion of roughage is fed. Apparently in this trial the concentrate-roughage ratio of 45–55 contained sufficient roughage for any advantage from antibiotic feeding to express itself. The rate of gain of the control lambs at both concentrate levels and the rate of gain of the lambs fed stilbestrol at both levels was nearly the same. However, lambs receiving antibiotic or antibiotic and stilbestrol, gained materially faster at the higher concentrate level than at the lower concentrate level. This suggests

TABLE 1. EFFECT OF AUREOMYCIN, STILBESTROL, AND AUREOMYCIN-STILBESTROL SUPPLEMENTS ON FATTENING LAMBS

	Roughage-concentrate ratio 45–55				Roughage-concentrate ratio 35–65			
Comparisons	Control Lot 1	Aureo. Lot 3	Auero. stil. Lot 5	Stilbestrol Lot 7	Control Lot 2	Aureo. Lot 4	Aureo stil. Lot 6	Stilbestrol Lot 8
No. lambs	10	10	10	10	10	10	10	10
Initial av. wt., lb.	63.3	63.3	64.1	63.4	62.6	63.7	63.8	63.9
Final av. wt., lb.	100.7	101.7	103.8	100.7	99.2	98.6	99.4	101.2
Gain/lamb, lb.	37.4	38.4	39.7	37.3	36.6	34.9	35.6	37.3
No. days fed	84	84	84	84	84	84	84	84
Av. daily gain, lb.	.445	.457	.472	.444	.436	.415	.424	.444
Av. daily feed consumption								
Grain	1.42	1.42	1.43	1.41	1.19	1.17	1.17	1.16
Hay	1.84	1.84	1.78	1.82	2.06	2.18	2.16	2.17
Protein supplement	.10	.10	.10	.10	.10	.10	.10	.10
Feed per 100 lb. gain								
Grain	319.3	310.7	301.5	317.1	273.8	280.0	275.3	262.2
Hay	413.1	401.0	377.3	408.6	473.8	524.9	509.8	489.5
Protein supplement	22.5	21.9	21.2	22.5	23.0	24.1	23.6	22.5
Carcass Data								
Yield %	49.5	49.5	49.4	49.5	49.5	48.9	49.1	48.9
Av. Grade [a]	4.5	5.0	4.9	4.6	3.9	5.3	4.6	3.9

[a] Choice 8, Good 5, Utility 2.

that about 50 percent concentrate in lamb fattening rations is not excessive when chlortetracycline is included. All of the lambs made satisfactory gains, indicating no depressing effect of the additives.

Although these lambs were hand fed, an effort was made to keep them on full feed at all times. Under these conditions neither the chlortetracycline, stilbestrol or a combination of the two seemed to affect average feed consumption.

Carcass Data

Due to the market discrimination of lambs weighing over 105 lb., it was necessary to slaughter these lambs before they were sufficiently finished to grade choice and prime. Treatment apparently affected the carcass grade but had no effect on carcass yield. At the higher level of concentrate feeding, lambs receiving antibiotic or antibiotic and stilbestrol graded slightly the highest. This was even more apparent at the lower concentrate level. Within a concentrate-roughage group, there was no difference in carcass grade between the control and the stilbestrol-fed lambs. The higher concentrate level produced higher grading carcassed as judged by the controls and the stilbestrol-fed lambs of the two groups. However, this advantage did not result when aureomycin was included in the ration. Antibiotic or antibiotic and stilbestrol-fed lambs graded approximately the same at both concentrate levels.

Summary and Conclusions

Under the conditions existing in this trial, 21.6 mg. of chlortetracycline (Aureomycin) per lamb daily, 2 mg. of stilbestrol per lamb daily or a combination of chlortetracycline and stilbestrol at those two levels had no significant effect on rate of gain, feed consumption or feed efficiency whether added to a ration with a concentrate-roughage ratio of 35–65 or 45–55. Carcass grade was slightly improved by the higher level of concentrate feeding and by chlortetracycline addition. Carcass yield was not affected by treatment or level of concentrate feeding.

Literature Cited

Bell, T. Donald and A. B. Erhart. 1955. Feedlot and pasture fattening tests with feeder lambs. Livestock Feeders Day, Kansas Agr. Exp. Sta.

Hale, W. H., C. C. Culbertson and W. E. Hammond. 1954. Ground corncobs, packing house animal feeding fat and diethylstilbestrol in the rations of fattening lambs. Agr. Ext. Ser., A. H. 678 Iowa State College.

Hatfield, E. E., U. S. Garrigus and H. W. Norton. 1954. Antibiotic supplements in rations for growing and fattening lambs. JOURNAL OF ANIMAL SCIENCE 13:715.

Jordan, P. S., R. M. Jordan and H. G. Croom. 1955. Effect of stilbestrol, progesterone-estradiol implants and oral administration of stilbestrol on fattening lambs. JOURNAL OF ANIMAL SCIENCE. In press.

Jordan, R. M. 1952. Effect of aureomycin on fattening lambs. JOURNAL OF ANIMAL SCIENCE 11:566.

Jordan, R. M. and T. Donald Bell. 1954. Effect of aureomycin supplement on suckling lambs. JOURNAL OF ANIMAL SCIENCE 13:450.

Perry, T. W., W. M. Beeson, E. C. Hornback and M. T. Mohler. 1954. Aureomycin for growing and fattening beef animals. JOURNAL OF ANIMAL SCIENCE 13:3.

HERITABILITY OF MULTIPLE BIRTH IN SHEEP

JAN RENDEL

The Royal Agricultural College [1]

IN any selection program, it is necessary to know the extent to which the variation of different traits is genetic in origin. Fertility is a factor of great economic importance to the sheep breeding industry. The big difference between breeds in the frequency of multiple births (Johansson and Hansson, 1943; Rendel, 1954) indicates that genetical factors have some influence. An early study by Marshall and Potts (1921), however, indicated that heredity plays a very limited role. Smirnov (1935), on the contrary, working with the highly prolific Romanov breed, found that fertility was a trait with fairly high repeatability. Ewes having singles, twins or triplets at their first lambings gave birth at later lambings to an average of 1.89, 2.15 and 2.68 lambs respectively. Thus, Smirnov points out that prolificacy in sheep seems to be a trait for which selection should be profitable. Johansson and Hansson (1943) made an extensive genetic analysis of the fertility of the different breeds of sheep in Sweden. The estimations of heritability were based on dam-daughter correlations within sires and the correlation between paternal half-sibs. The dam-daughter correlation for the first lambing in 1,300 Cheviots was insignificant. Thus selection based on the result of the first lambing would not increase the litter size in the following generations. However, when calculated on averages from three lambings, there was a highly significant dam-daughter correlation for lambing results (av. for all the four breeds $= 0.107$). Furthermore, the paternal half-sib correlation was 0.049. Thus, the heritability for the average litter size from three lambings could be estimated at about 0.20. Similar studies have been performed by Desai and Winters (1951), who determined the intra-sire regression of the lambing records of the daughters on those of their dams. The material comprised of 9 different lines of sheep (cross-breds and purebreds) with a total number of 74 rams, 542 dams and 639 daughters. The average number of dam-daughter pairs within line and sire was thus very small. It is therefore not surprising that the estimates of heritability varied largely within the different lines (from -0.4143 to 0.3379). Using two different methods of grouping the

[1] Institute of Animal Breeding, Uppsala, Sweden.

records of the mothers and their daughters, Desai and Winters (1951) arrived at average heritabilities of 0.0306 and 0.0736. According to the first method age—corresponding lambings of the mothers and daughters were paired, while according to the other one the average lambing record of the dam was compared with the average of all lambings of her daughters with the same sire. The first method seems undoubtedly to be the most accurate of the two. It did, however, decrease the number of pairs somewhat. For this reason Desai and Winters preferred the second procedure, which however must give a more or less erroneous result, unless the number of lambings of both the dams and daughters is large. The coefficient of repeatability, determined by the intra-class correlation method was 0.0498, which is lower than the estimate of heritability according to the second procedure.

The number of lambs per litter is not normally distributed but approaches the binomial distribution and the analyses of correlation, as used by Johansson and Hansson, cannot very well be applied to binomial data. Furthermore the results of Desai and Winters were—as already pointed out—based on such a limited and ununiform material that their results might be erroneous. It would therefore be of interest to estimate the heritability of multiple birth in sheep on a reasonably large material and according to methods applicable to binomial data. Two such methods have been used in the present paper.

Materials and Methods

Records from the four different breeds of sheep in Sweden, Cheviot, Oxforddown, Shropshire and Swedish Landrace are included in the study. The material has been collected by the Swedish Sheep Breeders' Association, who records fertility and other economically important traits in all purebred flocks registered in the herdbook. The records cover the period 1925–1942 and comprise in all 30,989 births.

Methods for estimations of the heritability for binomial data ("all or none traits") have been devised by Lush, Lamoreux and Hazel (1948) and by Robertson and Lerner (1949). Both of the methods were applied to mortality in chickens.

Lush *et al.* used the analysis of variance and the heritability was estimated from the correlation between half sibs. The sums of squares were calculated from $\frac{a\ (n-a)}{n}$, where a was the number of surviving hens and n those entering the laying house. However, the result will be the same, if the one alternative is given the value = 1 and the other one = 0,

and the sum of squares are calculated in the usual way. Thus this method does not differ principally from those generally used for calculations of heritability for continuous variates. The only restriction was that Lush *et al.* eliminated groups with less than 10 variates.

Robertson and Lerner estimated the heritability as the ratio between the average genotypical change and the selection differential. If no artificial selection is applied, there exists a natural selection for such traits as viability or incidence of multiple birth, since individuals with high viability or high fertility will get more offspring in the next generation than those having low viability or fertility. The expected genetical improvement over the previous generation is $\frac{\sigma_P^2}{\overline{P}}$ and the selection differential is $1 - \overline{P}$, where $\overline{P}$ is the mean and σ_P^2 the variance of the genotypical value of a trait, which phenotypically can only have the values 0 or 1.

Thus, $h^2 = \frac{\sigma_P^2}{\overline{P}\ (1 - \overline{P})}$

After determination of the geotypical variance Robertson and Lerner arrived to the following formula

$$h^2 = \frac{\sum \frac{a^2}{n} - \frac{(\Sigma a)^2}{\Sigma n} - (N - 1)}{\overline{P}\ (1 - \overline{P})\ r\ n_0}, \text{ where}$$

n = total number within groups, a = number of the one alternative, e.g. multiple birth, within groups, N = number of groups, r = difference of relationship within and between groups. $n_0 = n - \frac{\Sigma n^2}{\Sigma n} - (N - 1)$

The first term in the numerator is equal to the heterogeneity χ^2 in the $2 \times N$ table, which the data form.

Thus, $h^2 = \frac{\chi^2 - (N - 1)}{r\ n_0}$

Robertson and Lerner estimated the standard errors of heritability and repeatability according to the following formula (Fisher, 1941):

$$\sigma_t = [1 + (n - 1)\ t]\ (1 - t)\ \sqrt{\frac{2}{n\ (n - 1)\ (N - 2)}}$$

where t denotes the intra-class correlation. Heritability is equal to t/r and therefore the standard error of heritability can be estimated from $\frac{\sigma_t}{r}$.

In the present study, where the two methods for calculations of herita-

bility for "all or none traits" have been applied to fertility in sheep, the incidence of multiple birth has been given the value 1 and single birth 0. Only sire families with at least 5 ewes having 5 or more births each, have been included.

Results and Discussion

The scope of the study is shown in table 1.

The average number of births per ewe was 6.09. Some of the ewes were full sibs. In all there were—within the groups of ewes from the same sire—597 groups of full-sibs with an average of 2.08 ewes in each group.

The two methods for calculations of heritability for "all or none traits" can be used only in a case where no artificial selection for high fertility

TABLE 1. THE SCOPE OF THE STUDY

Breed	Total No. of births	No. of dams	No. of sires	No. of herds	Frequency of multiple birth
					%
Cheviot	12023	2055	185	39	49.1
Shropshire	10957	1778	133	25	46.6
Landrace	4148	636	57	12	69.1
Oxforddown	3861	624	50	7	51.0
Sum	30989	5093	425	85	Av. 51.1

has taken place. To test this the fertility of all ewes with complete lambing records between 2 and 5 years of age was compared with the fertility of all the ewes at corresponding ages. This comparison is shown in table 2. The figures in the columns A have been taken from Johansson and Hansson (1943), who used the same material as that in the present study. The difference between the two groups goes in both directions and is very small in all the breeds. Many herds have not taken part in the registration from the beginning, or the control has been dropped for intervals of different lengths. For this reason many of the ewes have entered the control, when 3 and 4 years of age but have then been used for several years. They are however assigned to group A in table 2. This might tend to decrease the difference between the columns B and A. To test the significance thereof 10 randomly picked Shropshire herds have been investigated according to a more powerful but also much more elaborate method. The lambing results of all 2 year old ewes present at

TABLE 2. FERTILITY AMONG SELECTED AND UNSELECTED EWES

(A = All Ewes; B = All Ewes with Complete Lambing Records Between 2 and 5 Years of Age)

	Cheviot					Shropshire					Oxforddown					Swedish Landrace				
	A		B		Difference	A		B		Difference	A		B		Difference	A		B		Difference
Age	No. of births	No. of lambs per birth	No. of births	No. of lambs per birth	B–A	No. of births	No. of lambs per birth	No. of births	No. of lambs per birth	B–A	No. of births	No. of lambs per birth	No. of births	No. of lambs per birth	B–A	No. of births	No. of lambs per birth	No. of births	No. of lambs per birth	B–A
1	418	1.04	41	1.02	—0.02	642	1.20	128	1.21	+0.01	262	1.23	65	1.25	+0.02	968	1.21	285	1.14	—0.07
2	6610	1.28	1620	1.31	+0.03	4030	1.37	1072	1.39	+0.02	1552	1.44	515	1.43	—0.01	1743	1.55	576	1.44	—0.11
3	5741	1.43	1620	1.45	+0.02	3280	1.47	1072	1.49	+0.02	1375	1.52	515	1.52	±0.00	1310	1.73	576	1.64	—0.09
4	4614	1.55	1620	1.57	+0.02	2710	1.54	1072	1.54	±0.00	1138	1.60	515	1.55	—0.05	969	1.85	576	1.77	—0.08
Sum and average	17383	1.40	4901	1.44	+0.04	10662	1.43	3344	1.46	+0.03	4327	1.49	1610	1.49	±0.00	4990	1.59	2013	1.55	—0.04

TABLE 3. FERTILITY AMONG SELECTED AND CULLED EWES AT THE SAME AGE WITHIN HERDS AND YEARS

Age	Culled ewes		Selected ewes		All ewes	
	Number of births	Number of lambs per birth	Number of births	Number of lambs per birth	Number of births	Number of lambs per birth
2	218	1.39	1302	1.37	1520	1.37
3	166	1.45	1206	1.44	1372	1.44
4	160	1.48	1037	1.52	1197	1.52
5	190	1.59	858	1.53	1050	1.54
Sum and average	736	1.47	4403	1.46	5139	1.46

3 years of age was compared with those of the ewes present at 2 but not 3 years of age. etc. for each successive pair of years. All the comparisons were made within herds, years and ages. The results given in table 3 show clearly that there has been no selection for high fertility. The two methods already referred to can therefore be used for calculations of heritability of multiple births.

The results of the analysis of variance are given in table 4. There were highly significant differences in fecundity between breeds, herds, half-sib groups and ewes. From the intra-sire correlation within breeds and herds the heritability can be estimated at $4 \times \frac{0.0074}{0.2353} = 0.13$. The coefficient of repeatability within breeds and herds is however somewhat

TABLE 4. ANALYSIS OF VARIANCE

Source of variance	d/f	Sum of square	Mean square	$\sigma 2$	Percentage of the total variance
Total	30988	7743.443	0.2499	0.2515	100
Between breeds	3	161.981	53.9936**	0.0062	2.5
Between herds	79	380.135	4.8118**	0.0106	4.2
Between sires	342	294.954	0.8624**	0.0074	2.9
Between ewes	4668	1492.207	0.3197**	0.0182	7.2
Within ewes	25896	5414.166	0.2091	0.2091	83.1

** P less than 0.001.

lower, namely 0.11. As stated above the half-sib groups also include some full-sibs. Thus the average genetical correlation within groups of half-sibs is somewhat higher than 0.25. This difference might have influenced the estimation of heritability to some extent. To test the significance thereof, the average genetical correlation between individuals having the same sire was calculated within one of the breeds (Shropshire). This breed had a total of 197 full-sib groups within the "half-sib groups." The average genetical correlation $\hat{r}_G$ for each group was calculated according to the formula:

$$\hat{r}_G = \frac{\left[\frac{n(n-1)}{2} - \sum\frac{b(b-1)}{2}\right]0.25 + 0.5\left(\sum\frac{b(b-1)}{2}\right)}{\frac{n(n-1)}{2}}$$

where n = No. of ewes within groups with the same sire
b = No. of ewes in each group of full-sibs, within groups of ewes with the same sire.

TABLE 5. ESTIMATES OF HERITABILITY AND REPEATABILITY WITHIN HERDS IN DIFFERENT BREEDS

Breed	Heritability	Repeatability
Cheviot	0.224	0.149
Shropshire	0.042	0.088
Landrace	0.088	0.062
Oxforddown	0.084	0.085
Average	0.126	0.109

The average genetical correlation within groups with the same sire was 0.256 in Shropshire. Thus the number of full-sibs was too small to increase the coefficient of relationship to such an extent that it could interfere with the results. The other three breeds had about the same proportion of full-sibs. It did not, therefore, seem necessary to make any corrections, and the ordinary genetical correlation within half-sib groups, 0.25, was used for all the breeds.

The estimates of heritability and repeatability varied largely within the different breeds. The results are summarized in table 5.

The results of the calculations according to the method of Robertson and Lerner (1949) are shown in table 6.

TABLE 6. CALCULATIONS BY METHOD OF ROBERTSON AND LERNER

Source of variance	$\Sigma\frac{a^2}{n} - \frac{[\Sigma(a)]^2}{\Sigma n}$ [a]	Difference	χ^2	Expected χ^2=N-1	n_0	r
Breeds	161.981					
Herds	542.116	294.954	1179.816	424	30457.689	0.25
Half-sib groups	837.070	1787.116	7148.464	5092	25890.725	1
Ewes	2329.277					

[a] For explanation of the symbols see page 195.

The estimates of heritability in the different breeds are summarized in table 7.

Comparing the figures in the tables No. 5 and 7 it is evident that the two methods used in this study show fairly good agreement. The ratios between the coefficients of heritability and repeatability for each breed rank with the exception of Oxforddown in the same order too, which shows that the sources of error (environmental differences between half-sib groups and a genetical correlation slightly higher than that for ordinary half-sib groups) have had about the same influence on both the methods. When the results of the two methods are averaged, the heritability for multiple birth in the four sheep breeds could be estimated to be 0.113 and the coefficient of repeatability 0.094. These results agree rather well with those of Johansson and Hansson (1943). They got a heritability of 0.214 according to the dam-daughter correlation method when based on the average of three lambings and of 0.196 when estimated from the half-sib correlation and based on the average of two lambings. These figures would correspond to heritabilities of 0.097 and 0.116 respectively when based on one lambing only. The two methods used in the present study seem, however, for theoretical reasons to be preferable for binomial data, even if they in this particular case did not yield results very different from those of Johansson and Hansson using

TABLE 7. ESTIMATES OF HERITABILITY AND REPEATABILITY AFTER THE METHOD OF ROBERTSON AND LERNER

Breed	Heritability	Repeatability
Cheviot	0.185 ± 0.023	0.120 ± 0.008
Shropshire	0.037 ± 0.011	0.067 ± 0.008
Landrace	0.062 ± 0.023	0.038 ± 0.011
Oxforddown	0.080 ± 0.020	0.073 ± 0.012
Average	0.099 ± 0.010	0.079 ± 0.005

conventional methods for calculations of heritability figures on normally distributed data.

It can therefore be concluded that the heritability of multiple birth in sheep is rather low (compare also the results of Desai and Winters discussed in a previous paragraph. Studies of the same trait in other species have given similar results. Korkman (1947) estimated the heritability for litter size in swine at 0.11. The frequency of twinning in different Scandinavian breeds of cattle had about the same or lower heritability (Korkman 1948 and Rasmusson 1954). It appears thus as if heredity has a rather limited influence on fecundity in most farm animals.

Summary

The heritability and repeatability of multiple birth in the four main sheep breeds of Sweden, Cheviot, Shropshire, Oxforddown and Swedish Landrace, have been estimated according to two different methods devised for "all or none traits." The material comprised 30,989 births. The two methods gave similar results. The average heritability and repeatability were 0.113 and 0.094 respectively.

Literature Cited

Desai, R. N. and L. M. Winters. 1951. The inheritance of fertility in sheep. Indian Jour. Vet. Sci. and Anim. Husb. 21:191.

Fisher, R. A. 1941. Statistical methods for research workers. 8th ed. 399 pp. Edinburgh: Oliver and Boyd.

Johansson, I. and A. Hansson. 1943. The sex ratio and multiple births in sheep. An. Agric. Coll. Sweden 11:145.

Korkman, N. 1947. Causes of variation in the size and weight of litters from sows. Acta Agriculturae Suecana 2:253.

Korkman, N. 1948. Genetic variation in the frequency of multiple births in cattle. Hereditas 34:23.

Lush, J. L., W. F. Lamoreux and L. N. Hazel. 1948. The heritability of resistance to death in the fowl. Poultry Sci. 27:375.

Marshall, F. R. and C. G. Potts. 1921. Flushing and other means of increasing lamb yield. U. S. Dept. of Agr. Bull. 996, 14 pp.

Rasmusson, M. 1954. Unpublished results. Manuscript at the Institute of Animal Breeding. Royal Agricultural College, Uppsala.

Rendel, J. 1954. De viktigaste produktionsegenskaperna hos får, variation och nedärvning. Kungl. Lantbr. Akad. Tidskr. 93:282.

Robertson, A. and M. Lerner. 1949. Heritability of all-or-none traits. Genetics 34:395.

Smirnov, L. 1935. Mnogoplodie romanovskik ovec. Probl. Zivotn. 8:7. (Animal Breeding Abstr. 1936, 4:195.)

TABLE 6. CALCULATIONS BY METHOD OF ROBERTSON AND LERNER

Source of variance	$\Sigma\frac{a^2}{n} - \frac{[\Sigma(a)]^2}{\Sigma n}$ [a]	Difference	χ^2	Expected χ^2=N-1	n_0	r
Breeds	161.981					
Herds	542.116	294.954	1179.816	424	30457.689	0.25
Half-sib groups	837.070	1787.116	7148.464	5092	25890.725	1
Ewes	2329.277					

[a] For explanation of the symbols see page 195.

The estimates of heritability in the different breeds are summarized in table 7.

Comparing the figures in the tables No. 5 and 7 it is evident that the two methods used in this study show fairly good agreement. The ratios between the coefficients of heritability and repeatability for each breed rank with the exception of Oxforddown in the same order too, which shows that the sources of error (environmental differences between half-sib groups and a genetical correlation slightly higher than that for ordinary half-sib groups) have had about the same influence on both the methods. When the results of the two methods are averaged, the heritability for multiple birth in the four sheep breeds could be estimated to be 0.113 and the coefficient of repeatability 0.094. These results agree rather well with those of Johansson and Hansson (1943). They got a heritability of 0.214 according to the dam-daughter correlation method when based on the average of three lambings and of 0.196 when estimated from the half-sib correlation and based on the average of two lambings. These figures would correspond to heritabilities of 0.097 and 0.116 respectively when based on one lambing only. The two methods used in the present study seem, however, for theoretical reasons to be preferable for binomial data, even if they in this particular case did not yield results very different from those of Johansson and Hansson using

TABLE 7. ESTIMATES OF HERITABILITY AND REPEATABILITY AFTER THE METHOD OF ROBERTSON AND LERNER

Breed	Heritability	Repeatability
Cheviot	0.185 ± 0.023	0.120 ± 0.008
Shropshire	0.037 ± 0.011	0.067 ± 0.008
Landrace	0.062 ± 0.023	0.038 ± 0.011
Oxforddown	0.080 ± 0.020	0.073 ± 0.012
Average	0.099 ± 0.010	0.079 ± 0.005

conventional methods for calculations of heritability figures on normally distributed data.

It can therefore be concluded that the heritability of multiple birth in sheep is rather low (compare also the results of Desai and Winters discussed in a previous paragraph. Studies of the same trait in other species have given similar results. Korkman (1947) estimated the heritability for litter size in swine at 0.11. The frequency of twinning in different Scandinavian breeds of cattle had about the same or lower heritability (Korkman 1948 and Rasmusson 1954). It appears thus as if heredity has a rather limited influence on fecundity in most farm animals.

Summary

The heritability and repeatability of multiple birth in the four main sheep breeds of Sweden, Cheviot, Shropshire, Oxforddown and Swedish Landrace, have been estimated according to two different methods devised for "all or none traits." The material comprised 30,989 births. The two methods gave similar results. The average heritability and repeatability were 0.113 and 0.094 respectively.

Literature Cited

Desai, R. N. and L. M. Winters. 1951. The inheritance of fertility in sheep. Indian Jour. Vet. Sci. and Anim. Husb. 21:191.

Fisher, R. A. 1941. Statistical methods for research workers. 8th ed. 399 pp. Edinburgh: Oliver and Boyd.

Johansson, I. and A. Hansson. 1943. The sex ratio and multiple births in sheep. An. Agric. Coll. Sweden 11:145.

Korkman, N. 1947. Causes of variation in the size and weight of litters from sows. Acta Agriculturae Suecana 2:253.

Korkman, N. 1948. Genetic variation in the frequency of multiple births in cattle. Hereditas 34:23.

Lush, J. L., W. F. Lamoreux and L. N. Hazel. 1948. The heritability of resistance to death in the fowl. Poultry Sci. 27:375.

Marshall, F. R. and C. G. Potts. 1921. Flushing and other means of increasing lamb yield. U. S. Dept. of Agr. Bull. 996, 14 pp.

Rasmusson, M. 1954. Unpublished results. Manuscript at the Institute of Animal Breeding. Royal Agricultural College, Uppsala.

Rendel, J. 1954. De viktigaste produktionsegenskaperna hos får, variation och nedärvning. Kungl. Lantbr. Akad. Tidskr. 93:282.

Robertson, A. and M. Lerner. 1949. Heritability of all-or-none traits. Genetics 34:395.

Smirnov, L. 1935. Mnogoplodie romanovskik ovec. Probl. Zivotn. 8:7. (Animal Breeding Abstr. 1936, 4:195.)

SOME ASPECTS OF TWIN VERSUS SINGLE LAMBS OF NAVAJO AND NAVAJO CROSSBRED EWES

GEORGE M. SIDWELL

United States Department of Agriculture [1]

THE desirability of twin lambs in range sheep production is often questioned by commercial producers, on the basis that although twins are profitable in years when feed conditions are abundant, they are unprofitable when feed conditions are poor. Single lambs are larger than twins at weaning time when breeding flock replacements are chosen. Unless twin lambs and single lambs are handled separately, twinning could be almost automatically selected against, since the producer is rarely certain which lambs are twins and which are singles and the larger lambs will be saved. This would be especially true of the ram lambs since a smaller proportion of them is saved.

The purposes of this study were to investigate the advantage in weight of lambs produced per ewe for ewes having single or twin lambs, weaning weights of single and twin lambs, survival rates of single and twin lambs, and heritability of type of birth.

Source of Data

The data used in this study are the lambing records and weanling records of the Navajo and Navajo crossbred sheep maintained at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico. All ewes lambing in 1947 through 1953, with the exception of 1951, were included.

The year 1951 was not included in the portion of the study dealing with weaning weight as all twin lambs were killed in a flash flood and hail storm that occurred shortly after lambing in the spring of 1951. This year is included in the portion of the study dealing with the heritability of type of birth.

The age of the dam, sex of the lamb, and age of the lamb have an influence on the weaning weight. Since unequal numbers of lambs were encountered, as far as age of dam, sex and ages of lambs were concerned, the data were corrected for these factors before attempting any analysis. The correction factors used have been previously published. Sidwell and Grandstaff (1949).

[1] Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, in cooperation with the New Mexico State College, and the Bureau of Indian Affairs, Washington, D. C.

TABLE 1. STATISTICS ON TWINNING

(ALL WEIGHTS ARE REPORTED IN POUNDS)

	1947	1948	1949	1950	1952	1953	Total
Navajo twins							
Number of Navajo ewes having twins	51	64	41	26	41	33	256
Number of Navajo twin lambs weaned	96	108	62	40	77	61	444
Average total weight of both twins per ewe	93.55	90.15	77.19	51.72	103.94	85.81	86.50
Average weight per Navajo lamb weaned	49.70	53.42	51.04	33.62	55.34	46.42	49.87
Navajo singles							
Number of Navajo ewes having singles	47	33	71	57	101	54	363
Number of Navajo single lambs weaned	44	28	61	54	94	51	332
Average total weight of single per ewe	57.21	51.15	51.78	44.79	61.94	53.81	54.30
Average weight per Navajo lamb weaned	61.11	60.29	60.27	47.28	65.37	56.97	59.37
Crossbred twins							
Number of crossbred ewes having twins	278	203	265	234	112	91	1183
Number of crossbred twin lambs weaned	452	327	383	305	204	163	1834
Average total weight of both twins per ewe	90.45	92.75	84.21	51.47	110.62	88.06	83.46
Average weight per crossbred lamb weaned	55.63	57.58	58.27	39.49	60.74	49.16	53.84
Crossbred singles							
Number of crossbred ewes having singles	304	350	478	607	628	211	2578
Number of crossbred single lambs weaned	253	317	388	520	547	187	2278
Average total weight of single per ewe	54.63	64.12	56.41	41.83	61.46	56.23	55.04
Average weight per crossbred lamb weaned	65.64	70.80	69.50	48.89	70.56	63.45	64.47

Results and Discussion

Data are presented in table 1 for breeding, type of birth and years, the number of ewes lambing, the number of lambs weaned, the average weight of lambs weaned per ewe lambing and the average weight of lambs weaned. The great yearly difference in pounds of lamb produced per ewe lambing and in the average weight of lambs weaned, probably justifies the opinion of many sheep producers in semi-arid regions that twins are not always desirable. It is difficult to market lambs as small as the 33- and 39-lb. twin lambs weaned in the drought year of 1950.

The value per pair of twins (86.5 lb.) at 20 cents per pound on a per ewe having twins basis, for the Navajo ewes, would be $17.30. For the Navajo ewes having singles (54.3 lb.) this value per ewe is $10.86. However, the small twin lambs will probably not sell for as much per pound as the larger single lambs, but the twin lambs could sell for as little as 12½ cents per pound and still equal the amount received for the single lambs selling for 20 cents per pound. These same values for the crossbred lambs are $16.69 per pair of twins (83.5 lb.) and $11.00 for single lambs (55.0 lb.). The twin lambs could sell for as little as 13 cents per pound and still equal the amount received for the single lambs selling at 20 cents per pound.

Since ewes in poor condition at breeding time tend to have fewer twins than ewes in good flesh, the number of twin lambs born in prolonged drought periods is automatically reduced. Terrill and Stoehr (1939) found in range sheep that the condition of the ewes during breeding has a close relation with the percentage of lambs born.

To examine the significance of observed differences between breeds, between types of birth and their intractions, it was necessary to use an unweighted analysis of year means, because unequal numbers of individuals entered each such mean. In each case the appropriate error is the interaction of the particular contrast with years, because we are concerned with what is the case for the population of possible years and not with what is the case for the particular years for which we have data. The magnitude of interactions of the contrasts with years may be judged approximately by comparing the appropriate mean square with the pooled mean square within years, type of birth and breed. An exact test is difficult because of the heterogeneity of this mean square.

The analysis of variance for pounds of lamb weaned per ewe for breed and type of birth are shown in table 2. The difference in weight of lambs weaned per ewe between breeds was not significant. However, the difference in weight of lambs weaned between ewes having singles and ewes

TABLE 2. ANALYSIS OF VARIANCE FOR POUNDS OF LAMB WEANED PER EWE FOR BREED AND TYPE OF BIRTH

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	9529.72	
Navajo vs. crossbred	1	35.53	35.53
Single vs. twins	1	5537.67	5537.67**
Years	5	3048.65	609.73**
Navajo vs. crossbred × single vs. twins	1	.06	.06
Navajo vs. crossbred × years	5	84.71	16.94
Single vs. twins × years	5	780.12	156.02**
Navajo vs. crossbred × single vs. twins × years	5	42.98	8.60

** Probability of chance occurrence less than 0.01.

having twins was highly significant. The non-significant mean square for the interaction of Navajo versus crossbred times years indicates that the Navajo ewes do not withstand severe drought conditions such as occurred in 1950 any better than the crossbred ewes. The Navajo and crossbred ewes tend to vary in the same direction and in the same magnitude within years. Regardless of the year involved the ewes having twins weaned more pounds of lamb than did the ewes having singles, although the differences varied with years as shown by the significant interaction between type at birth and years.

A similar analysis for weaning weight per lamb is presented in table 3. On a per lamb basis, the difference in weight of lambs is significantly

TABLE 3. ANALYSIS OF VARIANCE FOR AVERAGE POUNDS IN WEANING WEIGHT FOR BREED AND TYPE OF BIRTH OF LAMBS

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	2051.65	
Navajo vs. crossbred	1	197.68	197.68**
Single vs. twin	1	701.14	701.14**
Years	5	1113.91	222.80**
Navajo vs. crossbred × single vs. twins	1	1.61	1.61
Navajo vs. crossbred × years	5	14.48	2.89
Single vs. twins × years	5	4.82	.96
Navajo vs. crossbred × single vs. twins × years	5	18.00	3.60

** Probability of chance occurrence less than 0.01.

TABLE 4. SURVIVAL OF NAVAJO AND CROSSBRED SINGLE AND TWIN LAMBS

Item	Crossbred	Navajo
Number of twin lambs	2366	512
Dead	532	68
Alive	1834	444
Percent survival	77.5	86.7
Number of single lambs	2578	363
Dead	366	41
Alive	2212	322
Percent survival	85.8	88.7
Total ewes having twins	1183	256
Total ewes having singles	2578	363
Percent of ewes having twins	31.4	41.4

greater for crossbreds than for Navajo ewes. The weight of single lambs is also significantly greater than twin lambs.

The number of lambs, the survival rates of single and twin lambs and the difference between survival rates of Navajo and crossbred lambs is shown in table 4. The chi-square values in table 5 indicate that a higher percentage of single lambs than of twin lambs reach weaning age for the crossbred lambs, however this is not true of the Navajo lambs. Also, a higher death rate is observed in the crossbred twin lambs than in the Navajo twin lambs. The Navajo ewes also show a 10 percent advantage in the number of ewes having twins.

TABLE 5. CHI-SQUARE VALUES FOR TESTING SURVIVAL OF SINGLE AND TWIN LAMBS AND BREED DIFFERENCES

Item	Difference	Chi-square
Single minus twins		
Navajo	2.0	0.80
Crossbred	8.3	57.01**
All	7.0	49.93**
Navajo minus crossbred		
Twin	9.2	21.60**
Single	2.9	2.25
All	5.7	16.91**
Frequency of twinning		
Navajo minus crossbred	10.0	23.62**

** Significant at P .01.

Correlation Between Type of Birth of Dam and Her Offspring

The results of the preceding section indicate that ewes which give birth to twin lambs wean more pounds of lamb than do ewes which have singles. In measuring the correlation between type of birth of the dam and the type of birth of the offspring she produces, several factors need to be considered. Wentworth and Sweet (1917) reported that among the most important environmental and physiological factors which may exert a marked influence on the rate of twinning are the vigor of the ewe, the feeding of the ewe, the age of the ewe, the season and the region. Other workers have also shown a breed difference. Marshall and Potts (1921) stated that to get the largest number of twins, ewes should gain at least seven pounds during the breeding season. These workers also reported a breed difference in rate of twinning. Studying lambing records of mature ewes from nine different breeds representing 189 flocks, the percent of percent for the Dorset. This range is probably greater than the true range due to interflock differences. Williams and Cunningham (1916) lambs dropped ranged from 125 percent for Rambouillet ewes to 163 reported that Shropshire and Hampshire crosses as well as the purebred Shropshire were more productive of twins than the Tunis breed or its crosses with Shropshire and Hampshire. Dry (1936), Biegert (1938), Nozdracev (1939) and Desai and Winters (1951a) found that the percentage of twins born rises as the age of the dam increases up to the fifth or six year, then gradually declines. Kiser and Christagau (1940) reported that twin born ewes consistently give higher percentages of lambs than the single born ewes. Castle (1924) concluded that in the Bell flock, heredity had a relatively small influence on the occurrence of twinning.

The correlation between type of birth of the dam and her offspring was computed from a four cell (2×2) table, the four classifications being:

(a) Dams born as single, giving birth to single
(b) Dams born as single, giving birth to twins
(c) Dams born as twin, giving birth to single
(d) Dams born as twin, giving birth to twins.

The first dams considered in this study were born in 1946 and produced their first lambs in 1948. All ewes lambing after this date, up to and including 1953, were included. The correlation between type of birth of the dam and her offspring may not be the same in cases where the granddams are of different ages, but by including all ewes lambing (the

ewes were included regardless of whether the lambs lived or died) over the period 1948–1953, it is believed that a random sample was obtained.

The number of dam-offspring pairs and the correlation between the type of birth of the dam and the offspring she produced are given in table 6. These correlations were computed by years and by breed groups for the mature dams. However, due to the small number of two-year old ewes lambing each year, the correlations were not computed by years for the two-year old dams. The correlations shown for two-year old dams are only on a within-breed group basis.

In testing the significance of the correlation coefficients chi-square was computed, using the total number of observations involved. Only the

TABLE 6. CORRELATION BETWEEN TYPE OF BIRTH OF DAM AND OFFSPRING

	1949		1950		1951		1952		1953		All Years	
	N	r	N	r	N	r	N	r	N	r	N	r
Mature crossbred ewes	299	.04	544	.10	494	.08	344	.15**	154	.27**	1836	.11**
Mature Navajo ewes	34	.05	79	.13	119	.16	107	.06	87	.02	426	.06
2-year old crossbred ewes											844	.04
2-year old Navajo ewes											166	.20**

** Significant at P .01.

starred estimates in table 6 differ significantly from zero. Doubling these correlations gives estimates of the heritability of twinning. These estimates are reasonably close to a heritability of .14 calculated from the data of Rietz and Roberts (1915) for Shropshire sheep and that of .18 calculated from Wentworth's and Sweet's (1917) data for Southdown sheep. Both of these estimates may have been biased upward by interflock differences. An estimate of .14 was calculated from the data of Johansson and Hansson (1943). They stated that the heritability of twinning is probably .10–.15 based on one lambing and .15–.25 based on 3 or more lambings. Cockerham (1949) reported a heritability of .10, and Ercanbrack (1952) reported a heritability of .17 for Columbia and Targhee sheep. Wright and Stevens (1953) found 9.6 percent and 11.0 percent more lambs from twin ewes than from single ewes of Romney

and Corriedale sheep, respectively. Desai and Winters (1951b) estimated the heritability of fertility in sheep to be .0736 ± .0152. This estimate was by the intra-sire regression of the lambing record of the offspring on those of the dam.

The correlation of .11 for the mature crossbred ewes and .06 for the mature Navajo ewes between type of birth of the dam and the type of birth of the offspring reported here are probably biased downward due to lack of control of the physiological and environmental factors which affect this trait. Correlations this low indicate that relatively slow progress can be expected from selection for twins within this flock.

Summary

The advantage in weight of lambs produced by ewes having twins compared to ewes having singles, weaning weight of single and twin lambs, survival rates of single and twin lambs and heritability of type of birth was investigated for Navajo and Navajo crossbred ewes.

The difference in weight of lambs weaned per ewe between the two breeds studied was not significant. However, the difference in weight of lambs per ewe between ewes having singles, and ewes having twins, was highly significant. The interaction between Navajo versus crossbred times year was not significant, indicating the Navajo ewes do not withstand severe drought conditions any better than do the crossbred ewes. On a per lamb basis, the difference in weight of lambs weaned is significantly greater for crossbreds than for Navajo ewes. A significant difference was found in survival rates for crossbred single and twin lambs. This was not true for Navajo single and twin lambs. A higher death rate was observed in the crossbred twin lambs than in the Navajo twin lambs. The Navajo ewes show a 10 percent advantage in the number of ewes having twins. The heritability of twinning was found to be 22 and 12 percent, respectively, for mature crossbred and Navajo ewes.

Literature Cited

Biegert, K. 1938. Studies on twin pregnancy in the German Improved or Wurttemberg sheep, with special reference to the Hohenheim stud flock. Animal Breed. Abstr. 7:225.

Castle, W. E. 1924. The genetics of Multi-nippled sheep. Jour. Heredity. 15:75.

Cockerham, C. Clark. 1949. Estimates of repeatability and heritability in sheep. Unpublished M.S. Thesis, Raleigh, North Carolina.

Desai, R. N. and L. M. Winters. 1951a. An appraisal of factors affecting fertility in sheep. Indian Jour. Vet. Sci. An. Hus. 21:177.

Desai, R. N. and L. M. Winters. 1951b. The inheritance of fertility in sheep. Indian Jour. Vet. Sci. An. Hus. 21:191.

Dry, F. W. 1936. The genetics of the Wensleydale breed of sheep. Jour. Genetics. 33:123.

Ercanbrack, Sterling K. 1952. Selection indexes for range Rambouillet, Columbia and Targhee lambs. Unpublished Ph.D. Thesis, Ames, Iowa.

Johansson, Ivar and Arthur Hansson. 1943. The sex ratio and multiple births in sheep. Annals Agr. Coll. Sweden. II:145.

Kiser, O. M. and R. J. Christagau. 1940. Breeding for single and twin lamb production. Proc. Am. Soc. An. Prod. 182.

Marshall, F. R. and C. G. Potts. 1921. Flushing and other means of increasing lamb yields. U.S.D.A. Bul. No. 996.

Nozdracev, I. F. 1939. Selection of sheep for multiple births. Animal Breed. Abstr. 8:256.

Rietz, H. L. and E. Roberts. 1915. Degree of resemblance of parent and offspring with respect to birth as twins for registered Shropshire sheep. Jour. Agr. Res. 4:479.

Sidwell, George M. and J. O. Grandstaff. 1941. Size of lambs at weaning as a permanent characteristic of Navajo ewes. JOURNAL OF ANIMAL SCIENCE 8:373.

Terrill, C. E. and J. A. Stoehr. 1939. Reproduction in range sheep. Proc. Am. Soc. An. Prod. 369.

Wentworth, E. N. and J. B. Sweet. 1917. Inheritance of fertility in Southdown sheep. Am. Naturalist 51:662.

Williams, R. H. and W. S. Cunningham. 1916. Animal Husbandry. Arizona Agr. Exp. Sta. 27th Ann. Report. 281.

Wright, G. M. and P. G. Stevens. 1953. Lifetime wool production and breeding performance of Romney Marsh and Corriedale ewes. N. Z. Jour. Sci. and Tech. A34:430.

THE EFFECT OF CHLORTETRACYCLINE UPON DIGESTION OF RATION COMPONENTS, RETENTION OF NITROGEN AND VOLUME OF URINE EXCRETED BY SHEEP WITH OBSERVATIONS ON RECTAL TEMPERATURES

ALLEN D. TILLMAN AND ROBERT MACVICAR

Oklahoma Agricultural Experiment Station [1]

INCREASED growth rates and decreased incidence of scours has been noted when chlortetracycline (Aureomycin) was fed to young dairy calves. Rusoff and Davis (1951) reported that the greatest effect of the antibiotic was obtained when rumen development was not complete.

The observations with mature ruminant animals are less conclusive. Some workers (Colby *et al.*, 1950; Bell *et al.*, 1951) reported detrimental effects of high levels of chlortetracycline fed to either sheep or cattle. Others (Jordan, 1952; Bridges *et al.*, 1953; Perry *et al.*, 1953) reported beneficial results when lower levels were fed. This study was designed to study the effect with sheep of low levels of chlortetracycline upon the digestibility of ration components, the retention of nitrogen, the rectal temperature and the volume of urine excreted.

Experimental Procedure

First Trial

The basal ration was composed of equal parts of chopped prairie hay and a concentrate mixture composed of, in percent, ground yellow corn, 81.70; soybean oil meal, 11.00; urea (two-sixty-two) 3.04; steam bone meal, 2.90; sodium chloride, 1.00; sodium sulfate, 0.26; and a vitamin A-D feeding oil (3000 IU of vitamin A and 600 IU of vitamin D per gram), 0.10. The experimental ration was formed by adding 10 mg. of crystalline chlortetracycline per pound of concentrate mixture.

Ten 15-month-old western-type wether lambs weighing approximately 85 lb. were drenched with a preparation containing phenothiazine two weeks prior to being placed on the experiment. They were then transferred to metabolism stalls described by Briggs and Gallup (1949)

[1] Stillwater, published with the approval of the Director.

and each sheep was fed 908 gm. of the basal diet for 14 days. At this time they were randomly divided into two equal groups and continued on the same level of intake, with the experimental group receiving, in addition, 10 mg. of chlortetracycline per day. The sheep were kept on a constant feed intake during a successive 10-day preliminary period and a 10-day collection period. The details of collecting and handling of feces and urine were described by Tillman and Swift (1953).

At the completion of this phase, each animal was transferred to the alternate ration and the test repeated as previously described with two exceptions: (1) a 20-day preliminary period preceded the 10-day collection period, and (2) after the collection period ended all animals were continued on their respective rations for five days. During this period rectal temperatures and urine volumes for each animal were measured daily. The rectal temperature values were obtained with a regular veterinary thermometer standardized by comparison with a thermometer bearing a Bureau of Standards certification. The thermometer was inserted to a depth of 2 inches and allowed to remain in the rectum 3 minutes before reading. The temperatures were taken prior to the afternoon feeding.

Second Trial

Ten Dorset × Western (Dorset ram mated to western-type ewes) were used in this trial. These animals were about 7 months old and weighed an average of 56 lb. Equal parts of hay and concentrate were also fed in this trial. The concentrate mixture was the same as used in the first trial; however, much difficulty was experienced in getting these animals on feed, and it was necessary to feed long hay and to replace 10 percent of the prairie hay with good quality alfalfa hay in order to keep the animals consuming 600 gm. of total feed daily.

The switch back method was again used and other details relating to procedure have been described. In this trial rectal temperatures and urine volumes were obtained on all sheep.

Third Trial

Twelve western-type wether lambs which were about 12 months old and weighed an average of 71 lb. were used in this trial. The sheep were drenched with a preparation containing phenothiazine and transferred to the metabolism stalls. Six animals were fed the basal diet (composition and amount fed daily described in trial 1) and six were

fed the basal + 10 mg. of chlortetracycline per day for 28 days with urine volumes and rectal temperatures being taken during the last 5 days. The animals were then transferred to the alternate ration and the test repeated as before.

Fourth Trial

The animals used in the third trial were transferred to two large box stalls which were equipped with individual stanchions into which the animals were locked when eating. At all other times, they were allowed the freedom of the stall and free access to water. All other details were the same as described previously in the third trial except urine was not collected in the fourth trial.

TABLE 1. AVERAGE CHEMICAL COMPOSITION OF THE HAYS AND GRAIN MIXTURES (DRY MATTER BASIS)

Ingredient	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Organic matter	Energy
	%	%	%	%	%	%	%	Cal. per gram
Alfalfa hay (trial 2)	93.8	17.4	3.2	26.4	40.5	12.4	87.6	4.090
Prairie hay (all trials)	93.7	5.0	3.1	31.6	52.5	7.6	92.4	4.173
Basal grain mixture (all trials)	89.6	22.3	2.6	2.6	66.4	6.1	93.7	3.896
Basal plus antibiotic (all trials)	89.5	22.0	2.4	2.6	66.8	6.4	94.1	3.946

Fifth Trial

Nine western-type wether lambs which were about 7 months of age and averaging 56 lb. were divided into three groups. The first group of three (lot 1) received 600 gm. of the basal ration (trial 1). The three sheep in lot 2 received the basal plus 6.5 mg. of chlortetracycline per day while those in lot 3 received the basal plus 10 mg. aureomycin daily. After the first digestion phase was completed all sheep were fed the basal ration for thirty days and at the end of this period the nine animals were randomly placed on the three treatments and the trial repeated as before. All other details of this trial were described in trial 1 except that rectal temperatures and urine volumes were taken on all sheep in the fifth trial.

Chemical analyses of feed and excreta in all trials were conducted essentially by the methods of AOAC (1950). The gross energy was

determined in an Emerson fuel calorimeter equipped with an adiabatic chamber. The data were analyzed statistically by analysis of variance as described by Snedecor (1946). The proximate analysis of the hays and the concentrate mixture are shown in table 1.

Digestibility

The digestibility results are summarized in table 2. In the first trial the daily addition of 10 mg. of chlortetracycline to the basal ration did not affect ration digestibility. As the sheep used in this trial were older and larger than other sheep used in this series of trials, they were receiving 11.8 mg. of antibiotic per 100 lb. of body weight or, expressed another way, 11.0 mcg. of antibiotic per gm. of feed. When the test was repeated with smaller and younger sheep (Second trial), it was found that the daily addition of 10 mg. of antibiotic caused a statistically significant ($P < 0.05$) reduction in the digestibility of dry matter, protein, crude fiber, nitrogen-free extract and energy. The smaller sheep were receiving 15.4 mg. antibiotic per 100 lb. of body weight or 16.7 mcg. per gm. of feed. As there were minor differences between the composition of the hays fed in trials 1 and 2, the fifth trial was designed to study the effect of the two levels of chlortetracycline used in those trials. It was found that the 6.5 mg. level, which supplied 11.8 mg. per 100 lb. body weight, had no effect upon digestibility; confirming the observations of the first trial. The 10 mg. level, however, caused a significant reduction ($P < 0.05$) in the digestibility of dry matter, protein, crude fiber, nitrogen-free extract and energy; confirming the results of the second trial.

In all trials, the antibiotic-fed animals became accustomed to the rations much slower than those receiving only the basal ration. For example, in trial 1, the antibiotic-fed animals failed to consume all of their feed for the first 4 days after they were offered the ration. The basal group, at the same time, were consuming all of their rations. In the fifth trial, it required 20 days in order to get the antibiotic-fed animals to consume 600 gm. per day. The animals receiving the basal ration were consuming all of their ration within 3 days.

Nitrogen Retention

The nitrogen retention data, calculated as percentage of intake, are shown in table 2. The antibiotic did not affect the retention of nitrogen by sheep used in these trials.

TABLE 2. THE EFFECT OF CHLORTETRACYCLINE UPON DIGESTION, RETENTION OF NITROGEN, RECTAL TEMPERATURE, AND VOLUME OF URINE

Treatment	No. of sheep	Wt. of sheep	Digestion coefficients: Dry matter	Crude protein	Crude fiber	Nitrogen free extract	Energy	N. ret.	Rectal temp.	Urine vol.
					Trial 1 (age 15 months)					
								%	F.°	ml.
Basal	10	85.4	68.6	68.6	55.5	74.9	67.3	12.1	102.6*	898
Basal+10 mg.[a]	10	85.0	69.2	71.1	55.9	74.4	67.5	16.1	102.2	1136
					Trial 2 (age 7 months)					
Basal	10	55.8	70.2	72.4	64.6	79.2	70.1	11.5	102.4	455
Basal+10 mg.[a]	10	56.2	68.4*	69.8*	58.2**	75.4*	67.7*	9.5	102.2[b]	550
					Trial 3 (age 12 months)					
Basal	12	71.0							103.0*	394
Basal+10 mg.[a]	12	71.5							102.3	411
					Trial 4 (age 14 months)					
Basal	12	71.5							103.4*	
Basal+10 mg.[a]	12	71.5							103.0	
					Trial 5 (age 7 months)					
Basal	6	56.5	60.8	67.2	47.7	69.3	64.4	11.8	102.3	446
Basal+6.5 mg.[a]	6	56.0	61.3	69.7	51.7	69.7	65.7	8.7	102.2	496
Basal+10 mg.[a]	6	56.0	57.1*	64.3*	45.6*	66.7	61.9*	10.4	102.2	514

* Difference significant at the 5% level.
** Difference significant at the 1% level.
[a] Chlortetracycline per day.
[b] Difference significant at the 10% level.

Rectal Temperatures and Volume of Urine

In each of the five trials, the antibiotic-fed sheep had slightly lower rectal temperatures than their controls. The difference was statistically significant ($P < 0.05$) in trials 1, 3, 4 and when all trials were combined.

The antibiotic-fed sheep also excreted more urine than their controls; however, this difference was neither statistically significant in individual trial comparisons nor when all observations were combined. The fact that the antibiotic-fed animals, without exception, excreted more urine than their respective control animals suggests that the increase in urine volume was not due to chance.

Braude and Johnson (1953) observed that pigs receiving chlortetracycline excreted more urine than their controls and suggested that, with water intake remaining constant, the increased excretion would indicate a lowered rate of metabolism. The work of Knoebel and Black (1952) and Calesnick (1954) with rats supports the idea of reduced metabolic rate. The later works of Libby and Meites (1954) and Grant (1954), however, indicate that chlortetracycline had no pronounced effect upon the thyroid gland as measured by weight and/or uptake of radioiodine. It seems reasonable to assume that under certain conditions a broad spectrum antibiotic, such as chlortetracycline, should eliminate certain pathogens from the body, thereby lowering the body temperature and in this way could lower the rate of metabolism.

Summary

Three digestibility trials involving 58 sheep were conducted to study the effect of chlortetracycline upon the digestibility of ration components. It was found that a level of 11.8 mg. of chlortetracycline per 100 lb. body weight or 11 mcg. per gm. of feed had no effect upon ration digestibility. When the level was increased to 15.4 mg. per 100 lb. of body weight or 16.7 mcg. per gm. of feed there was a significant reduction in the digestibility of dry matter, crude protein, crude fiber, nitrogen-free extract and energy. The addition of either level of antibiotic had no effect upon nitrogen retention. Rectal temperatures were significantly depressed. The volume of urine excreted by sheep in these trials was increased slightly and consistently.

Literature Cited

Bell, M. C., C. K. Whitehair and W. D. Gallup. 1950. Effect of aureomycin on digestion in steers. Proc. Soc. Exp. Biol. Med. 76:384.

Braude, R. and B. C. Johnson. 1953. Effect of aureomycin on nitrogen and water metabolism in growing pigs. Jour. Nutr. 49:505.

Bridges, J. H., J. C. Miller, W. G. Kammlade, Jr. and H. O. Kunkel. 1953. Effects of various levels of aureomycin in fattening lambs. JOURNAL OF ANIMAL SCIENCE 12:660.

Briggs, H. M. and W. D. Gallup. 1949. Metabolism stalls for wethers and steers. JOURNAL OF ANIMAL SCIENCE 8:479.

Calesnick, B., W. D. Harris and R. W. Jones. 1954. Antithyroid action of antibiotics. Science 119:128.

Colby, R. W., F. A. Rau, and R. C. Dunn. 1950. Effect of feeding aureomycin to fattening lambs. Proc. Soc. Exp. Biol. Med. 75:234.

Grant, W. C. 1954. Aureomycin and the thyroid gland. Science 120:724.

Jordan, R. M. 1952. Aureomycin supplements in lamb fattening rations. JOURNAL OF ANIMAL SCIENCE 11:566.

Knoebel, L. K. and Alex Black. 1952. The influence of vitamin B_{12} and antibiotics on protein and energy utilization in a low protein diet. Jour. Nutr. 48:476.

Libby, D. A. and J. Meites. 1954. Negative effects of antibiotics on thyroid gland. Science 120:354.

Perry, T. W., W. M. Beeson, E. C. Hornback and M. T. Mohler. 1954. Aureomycin for growing and fattening beef animals. JOURNAL OF ANIMAL SCIENCE 13:3.

Rusoff, L. L., and A. V. Davis. 1951. Effect of aureomycin on growth of young dairy calves weaned from milk at an early age. Jour. Dairy Sci. 34:500.

Snedecor, G. W. 1946. Statistical methods applied to experiments in agriculture. Iowa State College Press, Ames, Iowa.

Tillman, A. D. and R. W. Swift. 1953. The utilization of ammoniated industrial by-products and urea by sheep. JOURNAL OF ANIMAL SCIENCE 12:201.

ESTIMATION OF CLEAN FLEECE WEIGHT FROM SMALL SIDE SAMPLES AND FROM WOOL DENSITY, BODY WEIGHT, STAPLE LENGTH AND GREASE FLEECE WEIGHT

GEORGE M. SIDWELL,[1] GORDON L. JESSUP, JR., AND W. D. MCFADDEN [2]

United States Department of Agriculture and
New Mexico Agricultural Experiment Station

THE amount of clean wool produced by the individual sheep is important in a breeding program designed for wool improvement, as clean wool is the most accurate measure of an animal's wool producing ability. In most cases, scouring the whole fleece is too costly and impracticable. Spencer *et al.* (1928) studied factors that influence wool production with Rambouillet sheep. Their estimate of clean fleece weight was based on small samples weighing about 1 pound. Schott and coworkers (1942), Pohle and Hazel (1944), and Pohle, Hazel and Keller (1945) scoured small samples from each fleece and found relations between whole fleece and sample ranging from .43 to .88, depending on the size and location of the sample. Terrill *et al.* (1945) estimated clean fleece weight from grease fleece weight and staple length with high accuracy. They found a correlation of .90 between a small side sample and whole fleece clean weight. Ali, Neale and McFadden (1953) have estimated clean fleece weight from wool density, body weight, staple length and grease fleece weight. Fox and Esplin (1954) used three individual sets of multiple regression equations involving staple length and grease fleece weight, staple length and body weight, heart girth and grease fleece weight, to predict clean fleece weight.

The amount of clean wool produced by each sheep is no doubt a function of the density of the fleece, the surface area on which it grows, and the length and fineness of the fibers. This work is an attempt to compare actual clean fleece weight with clean fleece weight estimated by three different methods and to develop multiple regression equations to predict clean fleece weight from wool density, body weight, staple length and grease fleece weight.

Journal Series No. 93, New Mexico Agricultural Experiment Station, State College, New Mexico.

[1] Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico in cooperation with the New Mexico State College and the Bureau of Indian Affairs, Washington, D. C.

[2] Assistant Agricultural Economist, New Mexico Agricultural Experiment Station, State College, New Mexico.

Materials and Methods

The data used in this study were collected from 334 ewes. These ewes were obtained by the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico from flock owners on the Navajo Indian Reservation. The exact age of each sheep is unknown, but all were in good health and were 2 years of age and older when these data were collected. In appearance they resembled low grade Rambouillet sheep.

These ewes were obtained in the winter of 1952–53. Just prior to shearing, in April of 1954, a small sample of wool weighing approximately 80 grams was taken from the left side of each sheep. This sample was immediately placed in a moisture-proof container, being scoured later in a soap and soda-ash solution and dried to a bone-dry basis. Later these samples were corrected for residual grease, vegetable matter and ash, and adjusted to standard conditions of 12 percent moisture, 1.5 percent extractables and 0.5 percent ash. The residual determinations were made at the New Mexico College of Agriculture and Mechanic Arts wool laboratory. At the same time the wool samples were taken, a small lock of wool was obtained from the left side of each ewe for staple length determination. Each sheep was individually weighed to the nearest pound. The density was determined with the use of the Neale Density Meter described by Ali, Neale and McFadden (1953). At shearing time each fleece was weighed to the nearest 0.05 pound then wrapped in cheesecloth to maintain the identity of each fleece. During the summer of 1954 these fleeces were scoured at the New Mexico College of Agriculture and Mechanic Arts wool laboratory. After scouring, each fleece was corrected for residual grease, vegetable matter and ash, and adjusted to standard conditions, as was done with the small samples.

In addition to estimating clean fleece weight by the use of small samples, this trait was predicted from density, staple length, body weight and grease fleece weight by a method described by Neale and McFadden (1954). Also, multiple regression equations were obtained to predict clean fleece weight from these same four traits. The data were analyzed statistically by the methods of Snedecor (1946).

Results and Discussion

Table 1 shows the mean and standard deviation for grease fleece weight, clean fleece weight, wool density, body weight, staple length and for the clean wool estimate obtained by the method described by

TABLE 1. MEANS AND STANDARD DEVIATIONS

Trait	Mean	Standard deviation
Grease fleece weight, lb.	5.83	1.06
Clean fleece weight, lb.	2.74	.59
Density, arbitrary	188.60	16.80
Body weight, lb.	89.10	9.90
Staple length, in.	2.06	.41
Clean fl. wt., method 1 [a]	2.31	.78
Clean fl. wt., method 2 [b]	2.33	.60
Clean fl. wt., method 3 [c]	2.34	.57

[a] Method of estimating clean fleece weight described by Neale and McFadden (1954).
[b] Small sample scoured, corrected for residuals and at standard conditions.
[c] Small sample scoured, uncorrected for residuals, but at standard conditions.

Neale and McFadden (1954) indicated by method 1. Method 2 is the clean fleece weight estimated by the corrected small sample and method 3 is the uncorrected sample estimate.

The correlation coefficients between each two variables are shown in table 2. Very little difference exists between actual clean fleece weight and clean fleece weight estimated by each of the three methods. The highest correlation is that between corrected and uncorrected sample estimates. In view of this high relationship and the small difference between the correlations involving methods 2 and 3 and between clean fleece weight and methods 2 and 3, it is doubtful that the expense of correcting small samples for residuals is necessary if a reasonably careful job of scouring the small samples is done.

The regression of each of the estimated clean fleece weights on actual clean fleece weight is given in table 3. The lowest standard error of estimate is associated with Method 1. From the results shown in tables 2 and 3, it appears that Method 1 could be used in lieu of the small

TABLE 2. CORRELATION COEFFICIENTS BETWEEN GREASE FLEECE WEIGHT, CLEAN FLEECE WEIGHT, AND THREE METHODS OF ESTIMATING CLEAN FLEECE WEIGHT

Item	Clean fleece weight	Method 1	Method 2	Method 3
Grease fleece weight	.81**	.81**	.70**	.67**
Clean fleece weight		.86**	.85**	.82**
Method 1			.78**	.78**
Method 2				.99**

** Significant at the 0.01 level.

TABLE 3. REGRESSION ANALYSIS OF CLEAN FLEECE WEIGHT ON ESTIMATED CLEAN FLEECE WEIGHT

Method	b	a	Sx.y
1	.65±.022	1.24	.307
2	.84±.029	.78	.315
3	.85±.033	.75	.336

sample procedure for predicting clean fleece weight. Although only slightly more accurate, it is by far less expensive and time consuming than small sample scouring.

The relationships among wool density, body weight, staple length, grease fleece weight and clean fleece weight are shown in table 4. Each of the four independent variables with the exception of density, are highly correlated with the dependent variable, clean fleece weight. Density in these data appears to have a highly significant negative relation with staple length, a low positive correlation with grease fleece weight, and no relation with body weight or clean fleece weight. The highest correlation is that between grease fleece weight and clean fleece weight.

The multiple regression prediction equations, along with the multiple correlation coefficients, are shown in table 5. Equation No. 1 considers all 4 independent variables; No. 2 omits density; No. 3 omits body weight; No. 4 omits staple length; No. 5 omits grease fleece weight; and, No. 6 omits both density and body weight. As can be seen by the multiple correlation coefficients, very little information is lost if density or body weight or both are omitted. However, when staple length is omitted, the R value drops from .91 to .82, and when grease fleece weight is omitted the value of R drops to .73. If measurements on all four of the independent variables are available, equation No. 1 should be used to predict clean fleece weight. Thus the estimated clean fleece

TABLE 4. CORRELATION COEFFICIENTS

Item	Body weight	Staple length	Grease fleece weight	Clean fleece weight
Density	−.01	−.39**	.13*	−.01
Body weight		.07	.28**	.31**
Staple length			.31**	.62**
Grease fleece weight				.81**

* Significant at the 0.05 level.
** Significant at the 0.01 level.

TABLE 5. PREDICTION EQUATIONS

Equation No.	Variable deleted	Partial regression coefficients of clean fleece weight on: Mean	Density (arbitrary)	Body weight lb.	Staple length in.	Grease fleece weight lb.	Coefficients
1	None	−1.74	.0034±.0009	.0066±.0014	.6690±.0394	.3440±.0041	.91
2	Density	−1.11		.0055±.0015	.5970±.0367	.3615±.0135	.90
3	Body wt.	−1.23	.0027±.0009		.6506±.0412	.3645±.0147	.90
4	Staple ln.	.47	−.0038±.0011	.0044±.0020		.4451±.0185	.82
5	Grease fl. wt.	−2.86	.0103±.0014	.0169±.0023	1.0437±.0593		.73
6	Density and body wt.	−.61			.6111±.0413	.3595±.0149	.89

weight of a ewe whose density is 200 units, body weight is 100 pounds, staple length is 2.00 inches and grease fleece weight is 5.00 pounds, is 2.66 pounds, i.e., $-1.74 + (.0034)(200) + (.0066)(100) + (.6690)(2.00) + (.3440)(5.00) = 2.66$. However, very little information is lost if both density and body weight are deleted and equation No. 6 could be used with almost as much accuracy as equation No. 1.

These equations are probably most applicable to short staple fine wool ewes raised under environmental conditions similar to those imposed in this study.

Summary

Three methods of estimating clean fleece weight were compared to clean fleece weight by scouring whole fleeces. A method described by Neale and McFadden (1954) appears to be as accurate and much less expensive than scouring small samples in estimating clean fleece weight. The correction of small scoured samples for residuals appears to be unnecessary if a reasonably careful job of scouring the samples is done. Multiple regression equations of clean fleece weight on wool density, body weight, staple length and grease fleece weight were calculated. As shown by the multiple correlation coefficients, very little information is lost if density or body weight or both are omitted. However, this may be true of only the sheep involved in this study. When staple length is omitted the R value drops from .91 to .82, and when grease fleece weight is omitted the R value drops to .73. When both density and body weight are omitted the R value only drops to .89. The multiple regression coefficients of clean fleece weight in pounds on staple length in inches and grease fleece weight in pounds were $.61 \pm .04$ and $.36 \pm .01$, respectively.

Literature Cited

Ali, K. T., P. E. Neale and W. D. McFadden. 1953. A rapid method for the estimation of clean fleece weight with the aid of a new wool density device. JOURNAL OF ANIMAL SCIENCE 12:165.

Fox, C. W. and A. L. Esplin. 1954. Measurements employed in estimating the individual clean fleece weights for crossbred wool-type ewes. Proc. Western Sec. Am. Soc. An. Prod.

Neale, P. E. and W. D. McFadden. 1954. A formula for selection of high producing sheep. New Mexico Agr. Exp. Sta. Press Bul. 1131.

Pohle, E. M. and L. N. Hazel. 1944. Clean wool yields in small samples from eight body regions as related to whole-fleece yields in four breeds of sheep. JOURNAL OF ANIMAL SCIENCE 3:159.

Pohle, E. M., L. N. Hazel and H. R. Keller. 1945. The influence of location and size of sample in predicting whole fleece clean yields. JOURNAL OF ANIMAL SCIENCE 4:104.

Schott, R. G., E. M. Pohle, D. A. Spencer and G. W. Brier. 1946. Wool yields in the small side-samples as related to individual whole-fleece yields in four bred-groups of sheep. JOURNAL OF ANIMAL SCIENCE 1:137.

Snedecor, G. W. 1946. Statistical Methods. Iowa State College Press, Ames, Iowa.

Spencer, D. A., J. I. Hardy and Mary J. Brandon. 1928. Factors that influence wool production with range Rambouillet sheep. U.S.D.A. Tech. Bul. 85.

Terrill, C. E., E. M. Pohle, L. O. Emik and L. N. Hazel. 1945. Estimation of clean-fleece weight from grease fleece weight and staple length. Jour. Agr. Res. 70:1.

THE LACK OF TOXICITY OF BIURET TO ANIMALS[1]

WILLIAM T. BERRY, JR., J. K. RIGGS AND H. O. KUNKEL
Texas Agricultural Experiment Station[2]

IT has long been known that urea upon heating is converted to biuret. The current methods in producing and conditioning both feed and fertilizer grade urea require a certain amount of heating and allow some biuret to be produced. The significance of a small amount of biuret as a contaminant in feed-urea has not been determined.

Belasco (1954) suggested that biuret was relatively inert to the activities of rumen microorganisms as tested by *in vitro* methods. Repp *et al.* (1955) indicated a slow release of ammonia from biuret in the digestive tract as shown by a slight elevation in blood ammonia and blood urea after administering biuret to lambs.

A need for thorough investigation of the toxicity and utilization of biuret by animals is indicated by recent reports of cases of biuret toxicity to plants. Sanford *et al.* (1954), Jones (1954), Armiger *et al.* (cited by Sanford *et al.*, 1954), and Haas and Brusca (1954) working with pineapple, citrus, perennial rye grass, and citrus and avocados, respectively, indicated that biuret either as a contaminant in fertilizer-urea or in rather pure form caused toxic symptoms varying directly in degree of severity with the level present.

A series of investigations were set up (1) to determine the toxicity of biuret fed continuously to animals, and (2) to study the effects of rations containing various combinations of urea and biuret.

Experimental Procedure and Materials

The general procedure was to incorporate biuret and urea in diets fed to rats, poultry, lambs, and steers. In the rat feeding, rat injection, and the poultry feeding studies, purified[3] biuret was used. A crude biuret-urea mixture was used in the lamb and steer feeding studies.

The method of Young (1954) and the Kjeldahl nitrogen method were used to determine the biuret content of the urea and biuret supplements

[1] Supported in part by a grant-in-aid from the Grand River Chemical Division of Deere and Company, Pryor, Oklahoma.
[2] Departments of Animal Husbandry and Biochemistry and Nutrition, College Station.
[3] Part of the purified biuret was obtained as a gift from the Allied Chemical and Dye Corporation through Dr. David F. Green. The crude biuret was supplied by Deere and Company.

mixed into the various diets. The purified biuret was 99.1 percent pure and contained 40.6 percent nitrogen on a dry basis. Upon exposure to the atmosphere, approximately 7 percent moisture was absorbed and on this basis the nitrogen content of ten samples was 37.5 percent.

The biuret content of the crude biuret-urea mixture varied from 58.1 percent to 63.9 percent, and the average of ten samples gave a value of 60.0 percent. By the urease method it was determined that the urea content of the crude biuret varied from 39.1 percent to 40.9 percent, an average value of 40.0 percent. Eight nitrogen determinations of the crude biuret gave an average of 40.7 percent (crude protein equivalent of 255 percent). This so closely approximated the crude protein equivalent of 262 percent for feed-urea that in all cases in the various rations the crude biuret was substituted gram for gram for the feed-urea.

The biuret content of eight different feed-urea samples which were used ranged from 0.88 percent to 2.29 percent. The average of 1.42 percent for all samples is an indication that the biuret content of feed-urea currently marketed is less than 5 percent and generally between 1 and 2 percent.

Rat Experiments

Procedure. Thirty-six weanling male rats of the Sprague-Dawley strain were randomly assorted according to weight into six groups of six each. The control group was fed a basal semi-purified diet known to support adequate growth (Richardson, 1954). Groups 2–6 were fed the basal diet to which C. P. biuret had been added at levels of 0.2 0.4, 0.6, 0.8, and 1.0 percent, respectively. After 30 days it was evident that rats could tolerate biuret in their diets up to 1 percent without any apparent effects and this phase of the experiment was terminated.

Animals in groups 1, 3 and 4 were used in a second experiment. The control group was continued as previously described. C. P. biuret was added to the basal diet at the rate of 5.0 percent and 10.0 percent and fed to groups 3 and 4, respectively. This feeding experiment was continued for 140 days to observe any long range effects of a high biuret diet.

On the 35th and 98th days, one randomly selected individual was removed from each of the three groups and sacrificed. The internal organs were removed and processed for histological studies by the Pathology Department of the School of Veterinary Medicine.

Results. There were no significant differences in growth rates among

either the six groups fed for only 30 days or the three test groups that were fed for 140 days. A summary of the treatments and the gains made in both experiments are presented in table 1.

The appetities were normal, all animals appeared thrifty throughout the duration of the experiment, and no illnesses or deaths occurred. All specimens submitted for histological studies were found to be normal. Slight changes which occurred could not be attributed to biuret toxicity. Since biuret is chemically related to urea it might be expected that the reaction of the rat body to biuret would be similiar to its reaction to

TABLE 1. EFFECTS OF VARIOUS LEVELS OF BIURET IN THE DIET OF LABORATORY RATS

Experiment	Days on test	Biuret level	No. of rats	Av. initial weight	Av. final weight	Av. gain
		%		gm.	gm.	gm.
I	30	0.0	6	36.0	175.6	139.6
		0.2	6	39.3	174.3	135.0
		0.4	6	39.0	169.3	130.3
		0.6	6	39.0	180.0	141.0
		0.8	6	34.6	177.0	142.4
		1.0	6	38.3	175.3	137.0
II	140	0.0	4	175.6	382.4	206.8
		5.0	4	169.3	372.4	203.1
		10.0	4	180.0	378.2	198.2

urea. Observation of a higher water intake among the biuret-fed groups with no evident histological changes was in agreement with the findings of Holman and Ener (1954) with urea.

Rat Injection Study

To investigate further the possible toxicity of biuret, parenteral administration was used. Eight 300- to 400-gm. male rats were assorted into a control and treatment group. All eight rats had been treated alike from weaning time. The four rats of each group were individually penned and continued on the purified diet previously described. Biuret of C. P. quality (150 mg.) was dissolved in a minimum volume of a physiological saline solution and administered by single daily peritoneal injections for a period of 21 days.

The uninjected group made an average daily gain of 2.38 gm. The average daily gain of the injected group was 2.05 gm. The difference in gain was not significant statistically. All individuals of both groups

maintained normal appetites, appeared thrifty, and none died. The slight difference in gain between the two groups was probably due to the daily use of the needle (the control group did not receive blank injections). After termination of injections the treated group made slightly higher gains than the control group during the next seven-day period.

On gross examination of the body cavity and organs of the injected and control animals the peritoneum of the injected ones showed slightly greater vascularity. Evidently the biuret was absorbed and eliminated without serious toxic effects.

TABLE 2. SUMMARY OF POULTRY FEEDING STUDY USING SOYBEAN OIL MEAL, UREA AND BIURET AS PROTEIN SUPPLEMENTS

Group No.	1	2	3	4
Supplement	Basal	Urea	Biuret	Soybean
Number	20	20	20	20
Av. initial wt., gm.	896.0	875.0	891.5	899.0
Av. final wt., gm.	1295.8	1268.5	1250.5	1557.0
Av. gain, gm.	399.8	393.5	359.0	458.0*
Composition of diet, percent				
Milo grain	83.5	82.5	82.5	75.5
Soybean oil meal	12.0	12.0	12.0	20.0
Urea	....	1.0	....	....
Biuret	....	....	1.0	....
Vitamin mixture	.5	.5	.5	.5
Mineral mixture	4.0	4.0	4.0	4.0
Total feed consumed, lb.	81.0	77.0	75.0	80.0
Feed per lb. gain, lb.	4.6	4.4	4.7	3.9
Calculated crude protein, percent	14.5	17.3	17.3	17.3

* Value significantly ($p<.05$) greater than for other groups.

Poultry Feeding Experiment

Procedure. Eighty New Hampshire pullets, 8 weeks of age, were randomly selected and divided into eight groups of 10 each according to weight. Four treatments permitted two groups of 10 within each treatment. Group 1 (control) was fed a milo-soybean meal basal ration calculated to contain 14.5 percent crude protein. It consisted of 83.5 percent milo grain, 12.0 percent soybean oil meal, 0.5 percent vitamin mixture, and 4.0 percent of a mineral mixture. Groups 2 and 3 were fed the same basal diet except 1 percent of the milo of each ration was replaced with 1 percent feed urea and 1 percent purified biuret, respectively, which raised the calculated crude protein equivalents to 17.3

percent. Group 4 was fed the basal diet with enough milo replaced by soybean oil meal to raise the calculated crude protein value to 17.3 percent.

Results. A summary of the treatments and results is presented in table 2. The rate of gain of the birds receiving the added soybean oil meal (Group 4) was significantly higher than that of the other three groups. The inclusion of biuret or urea had no statistically significant effect on the performance of the birds. They did not utilize the non-protein nitrogen additives which is in agreement with earlier findings (Carstens and Prufer, 1938; Heller and Penquite, 1941; and Bice and Dean, 1942).

Two pullets in the biuret-fed group suffered colds which affected the group's performance. If data from these two individuals are removed from consideration the daily gains and feed efficiency were equal to those of the basal group. No other illnesses occurred; all birds appeared thrifty, and it appears that neither urea nor biuret is toxic to eight-week-old pullets when added to the ration at this level. Feed consumption was about 5 percent lower for the NPN supplemented groups than for the control and soybean oil meal supplemented groups.

Lamb Experiments

Procedure. Twenty-seven fine-wool lambs, weighing 50–70 lb., were divided into three groups of nine each and for 84 days were fed rations consisting of 42.5 percent cottonseed hulls, 10.0 percent blackstrap molasses, and 40.0–45.5 percent ground milo. The various crude protein supplements were 7.5 percent cottonseed meal (Ration 1), 1.0 percent cottonseed meal plus 1.0 percent feed-urea (Ration 2), and 1.0 percent cottonseed meal plus 1.0 percent crude biuret (Ration 3). All three rations were calculated to supply equal levels of dry matter, total digestible nutrients and crude protein. In order to prevent differences related to palatability of the rations, the total intake of each group was adjusted to that of the lowest consuming group. This was accomplished by hand feeding twice daily. Cottonseed hulls were used as the roughage in an attempt to accentuate any effects of the biuret. Clark *et al.* (1951) noted that sheep fed low quality roughages showed toxic symptoms from urea more readily than those fed a legume hay. The 84-day feeding study extended from August 2, 1954, through October 25, 1954. Only medium gains were expected from these lambs because of the relatively high temperature during this period.

Results. The biuret group was the slowest, the urea group inter-

mediate, and the control group the fastest in cleaning up the rations. Thus, feed consumption of the biuret-fed group controlled the feed intake of the other groups. Daily observations indicated greater water intake and urination for the NPN-fed groups, these conditions being more apparent for the biuret group than for the urea group. The biuret group showed diuretic damper fleeces from the wet pen throughout the experiment.

Table 3 summarizes the results of this experiment. The similarity in average daily gains of the urea and biuret fed groups suggests that at

TABLE 3. SUMMARY OF LAMB FEEDING EXPERIMENTS USING COTTONSEED MEAL, UREA AND BIURET AS PROTEIN SUPPLEMENTS TO POOR QUALITY ROUGHAGE

Lot number	1	2	3
Supplement	C.S.M.	Urea	Biuret
Number	9	9	9
Av. initial weight, lb.	63.3	61.1	61.1
Av. final weight, lb.	82.1	77.1	76.3
Av. weight, lb.	72.7	69.1	68.7
Av. gain, lb.	18.8	16.0	15.2
Av. daily gain, lb.	.22	.19	.18
Average ration consumed			
Cottonseed hulls, lb.	.85	.85	.85
Molasses (blackstrap), lb.	.20	.20	.20
Milo grain, lb.	.80	.91	.91
Cottonseed meal, lb.	.15	.02	.02
Urea (feed), lb.	...	.02	...
Biuret (crude), lb.	...	...	.02
Calculated total digestible nutrients, %	59.6	59.9	59.9
Calculated crude protein equivalent, %	9.5	9.5	9.5
Dry matter consumed as % of body weight	2.75	2.89	2.91

the levels fed biuret may be utilized much the same as urea. At the termination of the experiment, one lamb from each group was slaughtered. An examination of the internal organs showed no changes. It was apparent that the consumption of the crude biuret-urea mixture or of urea alone did not cause toxic symptoms, unless the depression of appetite is considered a symptom.

High Level Feeding of Biuret. Two other lambs were individually penned and for 72 days were fed twice daily the same ration fed the control group in the previous study. Crude biuret was added to the

ration of one of the lambs to provide a level of 3 percent biuret and 2 percent urea. This addition of crude biuret to a cottonseed meal supplemented ration did not appear to reduce the rate of feed consumption. Gains were essentially the same, 25.5 and 25.0 lb. for the control and treated lamb, respectively. Although only two lambs were involved, the limited data indicated that biuret added in excess to a diet already adequate in protein was relatively inert. Even at this high level, approximately 68 gm. per day, no toxic symptoms or depression of appetite occurred.

Steer Feeding Experiment

Procedure. Forty-five yearling steers, 25 Angus and 20 Herefords, ranging in weight from 450 to 650 lb. were randomly assorted into five lots according to weight and breed. The five groups were fed a high-roughage, low-concentrate wintering ration in dry lot for 84 days. The basal ration was made up of 36.5 percent Atlas silage (hay basis), 24 percent cottonseed hulls, 6.0 percent alfalfa leaf meal, 11.0 percent blackstrap molasses, and from 13.0 percent to 20.0 percent milo grain, and 1.0 percent minerals (bonemeal and salt). The crude protein supplements used were 7.5 percent cottonseed meal (Ration 1), 1.0 percent feed-urea (Ration 2), 1.0 percent crude biuret (Ration 3), 1.5 percent of a mixture of crude biuret and feed-urea (Ration 4), and 1.25 percent of a urea-fatty acid complex (Ration 5).

The intake of each group was adjusted to that of the lowest consuming group by hand feeding. Each ration was calculated to supply equal amounts of dry matter, total digestible nutrients, and except for Ration 4, protein equivalent. Ration 4 was 1.4 percent higher in crude protein equivalent. The urea-fatty acid complex was 75 percent urea and 25 percent cottonseed foots.[4]

Results. As shown in table 4, the average gains made by the control group and the urea group (Ration 2) were not significantly different. However, when the urea was replaced with the crude biuret (Ration 3), a significantly lower gain resulted ($p<.01$). This group also consumed the least feed and therefore restricted the intake of the other lots, a condition also noted in the lamb feeding experiment. When additional urea (42 gm.) was included with the crude biuret (Ration 4), the average gain was increased 0.50 lb., a difference highly significant

[4] The urea-fatty acid complex was prepared by the Marco Chemical Company, Fort Worth, Texas, under the direction of Dr. Raymond Reiser.

statistically ($p<.01$). Thus, simply adding urea overcame the untoward effects of biuret.

Although this group (Ration 4) gained slightly more than the one fed urea alone (Ration 2), the difference was not significant. The increase of 0.18 lb. in daily gain may suggest that contrary to the results

TABLE 4. SUMMARY OF 84-DAY STUDY OF THE EFFECTS OF REPLACING COTTONSEED MEAL WITH UREA AND BIURET IN WINTERING RATIONS FOR STEERS

Lot number	1	2	3	4	5
Supplement	C.S.M.	Urea	Crude biuret	Crude biuret-urea	Urea-fatty acid
Number	9	9	9	9	9
Av. initial weight, lb.	522.7	523.7	523.7	522.9	523.3
Av. final weight, lb.	617.4	612.1	584.2	625.8	614.8
Av. gain, lb.	94.7	88.4	60.5	102.9	91.5
Av. daily gain, lb.	1.13**	1.05**	.72	1.23**	1.09*
Average ration consumed					
Silage, lb.	18.5	18.5	18.5	18.5	18.5
Cottonseed hulls, lb.	4.0	4.0	4.0	4.0	4.0
Molasses (blackstrap), lb.	1.8	1.8	1.8	1.8	1.8
Alfalfa leaf meal, lb.	1.0	1.0	1.0	1.0	1.0
Milo grain, lb.	2.2	3.4	3.4	3.4	3.3
Cottonseed meal, lb.	1.3	....	....	....	....
Urea, gm.	....	69	28	70	69
Biuret, gm.	....	1	42	42	1
Fat, gm.	....	....	....	....	23
Minerals, lb.	.14	.14	.14	.14	.14
Total	16.34	16.39	16.39	16.48	16.34
Dry matter consumed as % of body weight	2.86	2.88	2.95	2.85	2.87
Calculated ration composition					
Crude protein equiv., %	10.3	10.4	10.4	11.7	10.3
Total digestible nutrients, %	56.6	56.7	56.7	56.4	56.7

* Values significantly ($p<.05$) greater than for the group fed crude biuret alone.
** Value highly significantly ($p<.01$) greater than for group fed crude biuret alone.

obtained with Ration 3 the biuret nitrogen was utilized to some extent by the rumen bacteria.

The group fed urea-fatty acid complex (Ration 5) gained essentially the same as the urea fed group (Ration 2). Based upon this single study it appears that urea fed as a urea-fatty acid complex is efficiently utilized.

Summary and Conclusions

The effect of biuret in the diet of rats, poultry, lambs, and steers was investigated. Biuret produced neither acute nor chronic toxicity in these animals. It appeared to increase water consumption among lambs to a greater degree than did urea. It also appeared to depress appetite in both lambs and steers and gain in steers when compared with urea and feed protein. However, the depressing effect on appetite and gain was overcome apparently by including in a biuret ration adequate protein from cottonseed meal or higher levels of urea. The variable response with biuret suggests that this substance is not a dependable source of nitrogen for ruminants.

The limited value of biuret as a protein source and the fact that no toxic effects were observed in this series of experiments, indicates that the biuret content of commercial urea may be of greater concern when such urea is used as fertilizer than when it is used as a feed for animals.

Literature Cited

Belasco, I. J. 1954. New nitrogen feed compounds for ruminants. A laboratory evaluation. JOURNAL OF ANIMAL SCIENCE 13:601.

Bice, C. M. and L. A. Dean. 1942. Utilization of urea nitrogen by growing chicks. Poul. Sci. 21:15.

Carstens, P., and J. Prufer. 1938. Feeding amide flakes to laying hens. Zuchtungskunde 13:109.

Clark, R., W. Oyaert and J. I. Quin. 1951. Studies on the alimentary tract of the Merino sheep in South Africa. XXI. The toxicity of urea to sheep under different conditions. Onderstepoort Jour. Vet. Res. 25:73.

Haas, A. R. C. and J. N. Brusca. 1954. Leaf symptoms of toxic biuret. California Agr. 11:8.

Heller, V. G. and R. Penguite. 1941. The utilization of casein and amide nitrogen by chickens. Okla. Acad. Sci. Proc. 21:85.

Holman, R. T. and S. Ener. 1954. Use of urea inclusion compounds containing essential fatty acid in an experimental diet. Jour. Nutr. 53:461.

Jones, W. W. 1954. Biuret toxicity of urea foliage sprays on citrus plants. Science 120:3113.

Richardson, L. R. 1954. Unpublished data.

Repp, W. W., W. H. Hale, E. W. Chang and Wise Burroughs. 1955. The influence of oral administration of non-protein nitrogen feeding compounds upon blood ammonia and urea levels in lambs. JOURNAL OF ANIMAL SCIENCE 14:118.

Sanford, W. G., D. P. Gowing, H. Y. Young and R. W. Leper. 1954. Toxicity to pineapple plants of biuret found in urea fertilizers from different sources. Science 120:3117.

Young, H. Y. 1954. Determination of biuret in urea fertilizers. Personal communication.

THE GLUCOSE TOLERANCE TEST IN SWINE AND ITS IMPLICATIONS

IRBY M. BUNDING, MARK E. DAVENPORT, JR. AND MAURICE A. SCHOOLEY [1]

Armour Laboratories [2]

GROSS differences in growth rate, feed conversion and other criteria of efficiency have been observed between closely related strains or types of the economically important species of livestock. Until recently there have been few, if any, successful attempts to correlate these differences with biochemical characteristics. A simple biochemical or physiological indicator which correlates with certain physical characteristics would presumably be of considerable importance to the animal husbandryman. Harned and Cole (1939) observing two strains of rats with marked differences in growth rate and carcass composition, presented evidence which suggested that these differences may be related to differences in carbohydrate metabolism. Williams *et al.* (1949) suggested that distinctive patterns of metabolic traits are characteristic of individual human beings and certain laboratory animals. Recently, Kunkel *et al.* (1954) in an attempt to extend this concept reported that the pattern of glutathione metabolism in cattle has certain individual and breed characteristics.

In swine the metabolism of carbohydrate has been studied from a variety of aspects. Following the earlier work of Minkowski (1893) on the effects of partial pancreatectomy in swine, the report of Carlson and Drennan (1912) suggested that apparently normal swine have a poor tolerance for glucose. Biester (1925) described a case of diabetes in a single runt pig. Eveleth (1934) reported that swine are poor tolerators of glucose. The report of Hanawalt *et al.* (1947) appeared to be in conflict with some of this earlier work. However, Link (1953) indicated that pigs are susceptible to carbohydrate induced diabetes. Data from Catron *et al.* (1953) suggested that in swine there are individual differences in glucose tolerance. From this brief review there appears to be some controversy, but an appreciable volume of literature suggests that at least some swine are poor tolerators of glucose.

[1] We wish to give acknowledgment to Ralph Bloom, Armour Laboratories, Chicago, Illinois, for his technical assistance.

[2] Veterinary Research Department, Chicago, Illinois.

The present series of data was obtained in conjunction with a study of the effects of pituitary hormones on swine in which a number of observations were made on the ability of swine to tolerate a standard test load of glucose. The results of these tolerance tests are reported and the implications are discussed in terms of the published literature. These limited and preliminary observations are not intended as a definitive report but as a plea for additional investigations in this obviously neglected aspect of swine metabolism.

Materials and Methods

The mature lactating females and the growing fattening or stunted gilts and barrows used in these studies were for the most part of mixed breeding and representative of the presently available farm types. Except during the periods of enforced fasting no attempt was made to control the feed consumption of the test animals. In keeping with current standards of good management, the rations consisted of grains and supplements in quantities sufficient to meet the maintenance requirements of the individual animals concerned. The animals were housed in barns, sheds or special laboratory pens under essentially farm conditions. No special attempt was made to control or alter the tempterature, light, humidity or other environmental factors. Prior to the test period the animals were fasted overnight, generally for 16 to 24 hours. In accordance with the animal's weight, the test load of 0.5 or 1 gm. of glucose per pound body weight was given by stomach tube, or in a thin slop which the animals consumed voluntarily. Blood samples were collected from the ear veins into oxalated vessels at 0, ½, 1, 2 and 3 hours from the glucose loading. The blood glucose concentration was determined by the micro-method of Somogyi (1945).

Results

In figure 1 may be seen the glucose tolerance curves of six healthy, fattening litter-mate hogs ranging in weight from 199 lb. to 267 lb. The shapes of these curves appear to fall into two patterns. For animals 1, 2 and 3 there is a sharp or moderate rise at the one-half-hour interval following the ingestion of the test load of glucose. At one hour the level of glucose has fallen appreciably below the one-half-hour peak, and by the 2nd or 3rd hour has returned to approximately the fasting level. For animals 4, 5 and 6 the difference is best seen at one hour where instead

of falling, the blood glucose level continues to rise and remains high even at two hours. Comparing the weight classifications for the entire group of six animals, the mean weight of 237 lb. is exceeded by animals 1, 2 and 3 (those with the best tolerance), whereas animals 4, 5 and 6, having a distinctly poorer ability to tolerate or utilize the glucose test load, are well below the weight mean for the group as a whole.

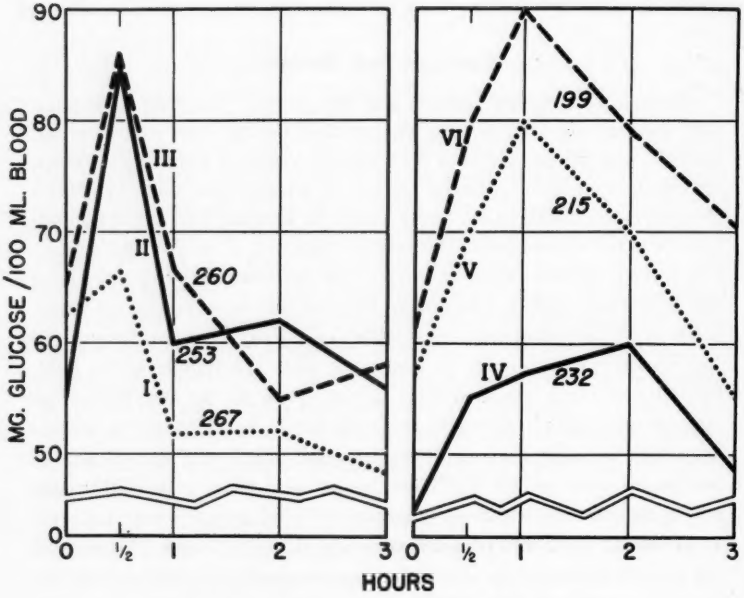


Figure 1. Glucose tolerance fattening hogs.

Figure 2 illustrates the pattern of glucose tolerance of four mature lactating sows located on an Illinois farm. Two of these animals show the rise in blood sugar extending into the second hour following the test meal, and two show an appreciable fall by the second hour. In no instance is the three-hour level below the fasting or 0-hour level. This is in contrast to the pattern seen in figure 1 for those animals showing a good tolerance.

In figure 3 the tolerance pattern of two groups of lactating Iowa [3] sows

[3] Animals made available to us through the courtesy of Dr. Damon Catron and the assistance of Mr. Vaughn Spear, Iowa State College, Ames, Iowa.

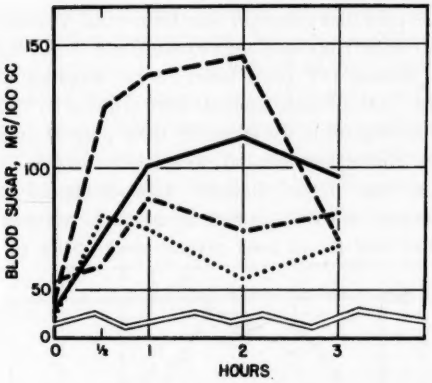


Figure 2. Glucose tolerance, lactating sows. Illinois farm.

shows the familiar rise through the one-half-hour, the 1-hour and 2-hour and, in some instances, 3-hour interval. The two animals showing the poorest tolerance (uppermost curves) may be classed as the "diabetic" type.

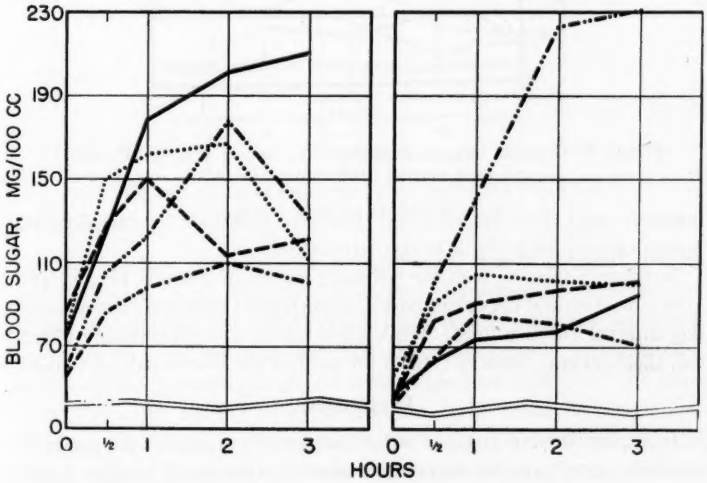


Figure 3. Glucose tolerances, lactating sows (Iowa).

In figure 4 the tolerance curves of four litter-mate Yorkshire pigs [4] may be seen. Animal 16M (top most curve) weighing 77 lb. has definitely a poor tolerance. Animal 15F (next lower curve) weighing 95 lb. also has a poor tolerance. Both of these animals were stunted by deliberate infection with hog cholera virus. In contrast, their normal litter mates, animals 1F and 2F (lower two curves), weigh 187 and 188 lb. respectively and are definitely not of the "diabetic" type. It should be pointed out that the two normal and two stunted animals had normal temperatures and were on full feed for at least several weeks prior to their glucose

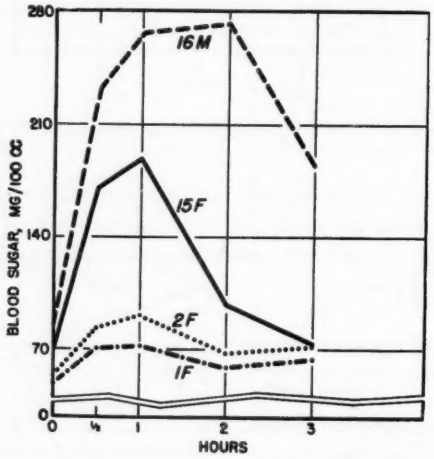


Figure 4. Glucose tolerance, stunted Yorkshire pigs (15F, 16M) and their normal litter mates (1F, 2F).

tolerance tests. This suggests that their poor tolerance for carbohydrate is not due to either a febrile or starvation effect.

In figure 5 may be seen the tolerance curves of animals 1F and 15F (the lower two and upper two curves respectively) repeated after a seven-day interval (broken lines). While these curves are not precisely identical, their general shape is typical for each of the individuals concerned.

Discussion

In a miscellaneous group of swine, presumably typical of the presently available farm types, an appreciable number were found to show a poor

[4] Data made available through the courtesy of Dr. J. A. Baker, Veterinary Virus Research Institute, Cornell University, Ithaca.

tolerance for carbohydrate. The capacity to tolerate glucose does not seem to be associated with particular physiological states e.g., lactation or fattening, but appears to be an individual characteristic. Within a limited time interval the tolerance pattern appears to be a consistent individual characteristic. There also appears to be a relationship between the existence of certain disease processes and a poor tolerance for carbohydrate in swine. Unfortunately we do not have a precise definition for diabetes in swine nor does the presently available information allow us

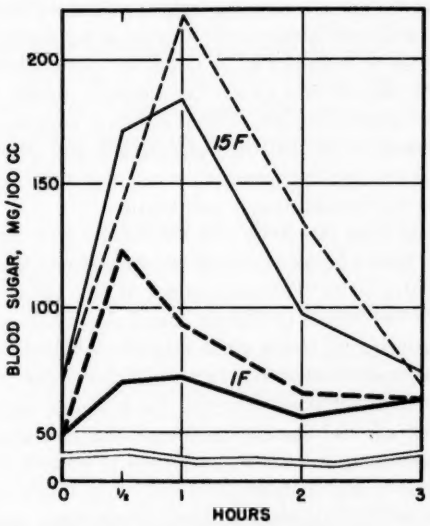


Figure 5. Glucose tolerance curves animals 1F and 15F repeated after seven day interval.

to differentiate a hyperglycemic responsiveness due to a disease process and that which is an inherent (metabolic) characteristic of the animal. It does not appear that differences in the principle nutrients are associated with the poor tolerance observed, for most certainly within groups, and probably between groups, all animals received essentially the same diets. Generally, when a poor tolerance for carbohydrate is conditioned by diet, the rations are found to be low in carbohydrate and high in protein or fat. Therefore, the observation that swine are poor tolerators of carbohydrate first mentioned by Carlson (1912) becomes somewhat

surprising in view of the substantial amounts of carbohydrate found in most swine rations.

While the dangers of drawing analogies between divergent species are obvious, it is at least interesting to point out that swine have many of the characteristics of the adult human diabetic. In light of the efforts of the swine husbandrymen to breed animals for extraordinary obesity and for large birth weights, it is also interesting to consider the report of Jackson (1954) which suggests that in the human the tendency to produce large babies is a partially inherited characteristic combined with the tendency to diabetes passed on by the male as well as the female. Whether the tendency for a poor tolerance for glucose which appears to exist in swine is desirable or undesirable in terms of the requirements of the swine industry is beyond our present knowledge to answer, however, the "diabetic" type appears to occur with a sufficient frequency to warrant the concerted attention of the swine physiologist and swine husbandryman. It is suggested that the glucose tolerance test may provide an additional means for the classification of swine types.

It also appears from this study that the rapidly growing swine (more efficient?) may have a better tolerance for glucose than the slower growing (less efficient?) swine. This may appear at first glance to be contradictory to the observations of Harned and Cole (1939) who found an obese rapidly growing rat strain would tolerate carbohydrate less readily than a lean slower growing strain. In view of this apparent discrepancy it is well to consider the possibility that the tolerance for carbohydrate may change with age and that the rapidly growing animal may on reaching maturity, become a less efficient tolerator of glucose. It should also be borne in mind that a comparison of individual differences might not be comparable to strain differences particularly when comparisons are drawn between two species.

The glucose tolerance test is laborious and time consuming so that to continue this line of investigation it would be of utmost importance to have a simplified procedure for measuring glucose tolerance. It is possible that a test like the Exton Rose (1934) or a simplified chromatographic procedure would be useful in this connection. The fact that swine are known to have a propensity for coprophagy may account for some of the reports suggesting that swine have a delayed absorption time, therefore due precaution should be taken to maintain clean pens during the test period.

A clear distinction also should be drawn between mature and young growing animals for it has been adequately demonstrated by Young

(1953) and others that in certain species the young animal is less susceptible to the diabetes induced by pancreatectomy or the administration of pituitary diabetogenic hormones. This fact may account for the apparent discrepancy between the reports which indicate that swine are apparently good tolerators of glucose (based for the most part on experiments in which young or immature animals were used for experimental subjects) and this report and others that indicate that some swine are poor tolerators of glucose.

Summary

Additional data are presented which indicates that a "diabetic-like" syndrome may exist in swine and that the ability to tolerate glucose may be associated with other individualizing characteristics of swine. Of 24 animals studied in this series three, or one out of eight, present a "diabetic" type tolerance curve.

Literature Cited

Biester, H. E. 1925. Diabetes in a pig showing pancreatic lesions. Am. Vet. Med. Assoc. Jour. 67:99.

Carlson, A. J. and F. M. Drennan. 1912. A note on the sugar tolerance in the pig. Jour. Biol. Chem. 13:465.

Catron, D. V., M. D. Lane, L. Y. Quinn, G. C. Ashton and H. M. Maddock. 1953. Mode of action of antibiotics in swine nutrition. I. Effect of feeding antibiotics on blood glucose. Antibiotics & Chemotherapy 3:571.

Eveleth, D. F. 1934. The blood chemistry of swine. I. Blood changes following the ingestion of glucose. Jour. Biol. Chem. 104:559.

Exton, W. G. and A. R. Rose. 1934. The one hour, two dose dextrose tolerance test. Am. J. Clinical Path. 4:381.

Hanawalt, V. M., R. P. Link and J. Sampson. 1947. Intravenous carbohydrate tolerance tests on swine. Proc. Soc. Exper. Biol. & Med. 65:41.

Harned, B. L. and V. V. Cole. 1939. Evidence of hyperfunction of the anterior pituitary in a strain of rats. Endocrinol. 25:689.

Jackson, W. P. U. 1954. The prediabetic syndrome. Large babies and the (pre) diabetic father. Clin. Endocrinol. Metabolism 14:177.

Kunkel, H. O., E. C. Stutts and R. R. Shrode. 1954. The individuality of the level of blood glutathione in young beef cattle. JOURNAL OF ANIMAL SCIENCE 13:852.

Link, R. P. 1953. A study of the effect of repeated intraperitoneal injections of glucose in pigs. Am. Jour. Vet. Res. 14:150.

Minkowski, O. 1893. Diabetes mellitus nach pankreasexstipation. Arch. f. exp. Path. u. Pharmakol. 31:93.

Somogyi, M. 1945. Determination of blood sugar. Jour. Biol. Chem. 160:69.

Williams, R. J., L. J. Berry and E. Beerstecher, Jr. 1949. Individual metabolic patterns, alcoholism, genetotrophic diseases. Proc. Natl. Acad. Sci. 35:265.

Young, F. G. 1953. Growth hormone and diabetes. Recent Progress in Hormone Research 8:471.

A GENETIC STUDY OF WEIGHT AT FIVE AGES IN HAMPSHIRE SWINE [1, 2]

JAMES V. CRAIG,[3] H. W. NORTON AND S. W. TERRILL

Illinois Agricultural Experiment Station [4]

THE economic importance of gaining ability in market hogs is clear. It has been shown by a number of investigators (Evvard *et al.*, 1927; Lush, 1936; Dickerson and Grimes, 1947; Baird *et al.*, 1952) that rapid gains and efficient use of feed are associated to a marked degree. Weight for age is easier and less costly to measure than efficiency of feed use and hence is a useful criterion in selecting for more efficient gains. The shorter feeding period necessary with fast-gaining pigs to produce swine of market weight also reduces costs of production and risk of loss due to disease and accident.

Krider *et al.* (1946) have reported the results of four generations of selection for rapid and slow gains in Hampshire swine. The present study is an extension of the same experiment to ten generations of selection for rapid gains and eight generations of selection for slow gains. A total of 2036 pigs produced in 288 litters in 124 sire-groups are involved. Estimates of sex differences, heritabilities, and genetic correlations for weights at five ages from birth to 180 days are presented.

Material and Methods

Foundation animals for this study were obtained in 1939 by purchasing at weaning 41 boar and 42 gilt pigs of the Hampshire breed from 48 Illinois herds. These pigs were spring-farrowed and were fed to 180 days of age at the Illinois Station. Lines were set up by selecting the heaviest five boars and 15 gilts and the lightest five boars and 15 gilts for the Rapid and Slow lines, respectively. Each line was thereafter maintained as a closed herd.

[1] In cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Agricultural Research Service, USDA.

[2] The authors wish to acknowledge the contributions of J. L. Krider, B. W. Fairbanks, W. E. Carroll and E. Roberts in initiating and carrying out this experiment in its early stages. Thanks are due M. C. Nesheim for aid in tabulating and analyzing data and to R. H. McDade and associates for helping in the collection of data.

[3] Present address: Poultry Husbandry, Kansas State College, Manhattan.

[4] Urbana, Ill.

Each generation in each line was produced by using from four to seven (usually five) boars to sire from 6 to 17 litters. All pigs were fed together on pasture until 4 or 5 months of age when the boars were separated from the gilts. Selection was based solely on 180-day weight in 1939, 1940 and 1941, on 150-day weight in 1942 and 1943, and on 154-day weight in all subsequent years, with the restriction that only one boar was used from any one litter in order to minimize inbreeding. Because of this practice and because of the relatively high proportion of boars used per line, selection differentials were not maximum. Matings among selected animals were made so as to avoid inbreeding as far as possible. Maximum average levels of inbreeding, attained in the last years of the experiment, were 0.13 for both Rapid and Slow lines; whereas, the mean inbreeding of pigs for the ten-year period was 0.048, as calculated from Wright's (1922) formula.

All boars were kept to 180 days of age without castration. Individual pig weights were available for birth, 21, 56, 154 and 180 days of age. All gilt weights were adjusted to male equivalents in order to compare the two lines on an equal sex basis. No weights were recorded for the pigs purchased in 1939 before 150 days of age. Twenty-one-day weights were not taken in the 1943 spring season and 154-day weights were not obtained for fall farrowed pigs in 1940, 1941 and 1942.

Spring litters were produced by gilts, with only a few exceptions. Slow-line pigs in 1944 and 1948 were out of two-year-old sows because of exceptionally slow growth of pigs in this line in the 1943 and 1947 seasons. Rapid-line gilts and two-year-old sows were both used in producing pigs in 1948 and 1949. Fall litters were produced in 1940, 1941 and 1942, from sows farrowing for the first time in the spring of the same year. Except for 154- and 180-day weights, which were assumed to be primarily free of maternal effects, comparisons between lines were restricted to pigs produced by dams of the same age.

Standard statistical techniques were used in analyzing the data, as will be described with the results.

Results

Effect of Sex on Weight for Age

Differences found by subtracting the mean female weight from the mean male weight in litters having both sexes present were weighted according to the numbers of observations in each and subjected to an analysis of variance, table 1. Litter and sire interactions with sex were

tested, and no significance found. Mean squares for line, season, year-generation and interaction of line by year-generation were found, by the method of fitting constants, for 180-day weight only. Subclass mean squares were not large enough at other ages to suggest significant differences for these variables. Sex was found to have a significant effect on weight at all ages.

TABLE 1. ANALYSIS OF VARIANCE FOR EFFECT OF SEX ON WEIGHT AT FIVE AGES [a]

	Age in days									
	0		21		56		154		180	
Source of variation	D/F	M. S.	D/F	M. S.	D/F	M. S.	D/F	M. S.	D/F	M. S.
Sex	1	8.66**	1	16.3*	1	116.8*	1	2087*	1	4848**
Line, season and year—generation subclasses [b]	26	0.11	25	1.4	26	26.7	21	418	26	798
Sex X sire [c]	95	0.13	84	2.1	91	22.5	67	477	77	574
Sex X litter [c]	145	0.13	104	2.9	108	23.2	77	400	85	637
Between littermates of same sex	1426	0.16	924	2.8	887	22.9	532	358	593	548

[a] Analysis based on intra-litter sex differences, weighted as follows: (x male weight − x female weight) (w), where w = (n males) (n females)/(n males + n females).

[b] Subclasses analyzed only for 180-day weight sex differences where the mean square was large enough to indicate that significant differences among components might be found. Resulting mean squares are: Line (1 D/F) 267, Season (1 D/F) 595, Year-generations (9 D/F) 1677* and Line X Year-generations (15 D/F) 316.

[c] Within subclasses.

* Significant at 5 percent level.

** Significant at 1 percent level.

Mean male and female weights were computed for all ages, giving equal emphasis to the means of the Rapid and Slow lines as shown in table 2. It is seen that sex caused progressive absolute weight differences in favor of the boars ranging from 0.134 lb. at birth to 4.5 lb. at 180 days. The relative difference between sexes was about 5 percent at birth but was significantly less for the other ages, averaging about 3 percent. Adjustment factors shown in the last column of table 2 were used for converting female weights to male equivalents. The factor shown for 180-day weight was not used because of the year-generation differences found for this trait, but is included to indicate the average relative sex difference at this age. Constants fitted for 180-day weights by year-generations were used in making adjustments at that age.

Heritability Estimates

Line Differences Resulting from Selection. The effectiveness of mass selection for heavy and light weight at 154 or 180 days of age is shown by the differences produced between unselected progeny weights of the

TABLE 2. EFFECT OF SEX ON WEIGHT AT FIVE AGES, AND ADJUSTMENT FACTORS FOR SEX

	Breeding group involved											
	Illinois rapid line				Illinois slow line				Combined [a]			
	Males		Females		Males		Females					
Age	No.	wt.	No.	wt.	No.	wt.	No.	wt.	Males wt.	Females wt.	Difference	Adjustment factor [b]
days		lb.		lb.		lb.		lb.	lb.	lb.	lb.	
0	559	2.667	504	2.543	472	2.693	423	2.548	2.680	2.546	0.134**	1.053
21	386	10.28	349	9.99	320	9.99	279	9.85	10.14	9.92	0.22*	1.022
56	389	26.21	361	25.40	313	23.68	276	23.30	24.95	24.35	0.60*	1.025
154	258	114.3	233	112.7	192	96.7	179	92.0	105.5	102.4	3.1*	1.031
180	285	147.5	267	144.1	213	126.8	205	121.2	137.2	132.7	4.5**	1.034 [c]

[a] Rapid and Slow lines given equal weight.
[b] To adjust female weights to male equivalent.
[c] Not used because of significant year-generation effects on the sex difference at 180 days of age.
* Significant at 5 percent level.
** Significant at 1 percent level.

TABLE 3. WEIGHTS AT 154 AND 180 DAYS OF AGE IN THE RAPID AND SLOW LINES AND HERITABILITY (h^2) ESTIMATES BASED ON LINE DIFFERENCES [a]

Year	Season	Selection generation		154 days of age					180 days of age				
				Weights		Differences (R–S)			Weights		Differences (R–S)		
		Rapid	Slow	Rapid	Slow	Selected [b]	Actual	h^2	Rapid	Slow	Selected [b]	Actual	h^2
1939	Spring	0	0	115.6		....	....	...	147.2		....	....	...
1940	Spring	1	1	109.6	101.6	33.7	8.0	.24	147.0	132.2	52.4	14.8*	.28
1940	Fall	1	1	....	....	....	....	...	134.0	129.4	53.4	4.6	.09
1941	Spring	2	2	125.6	117.4	73.2	8.2	.11	163.1	153.2	105.8	9.9	.09
1941	Fall	2	2	....	....	....	....	...	122.6	103.9	104.5	18.7	.18
1942	Spring	3	3	106.3	80.2	111.9	26.1**	.23	143.7	110.4	152.9	33.3**	.22
1942	Fall	3	3	....	....	....	....	...	150.9	112.5	136.7	38.4**	.28
1943	Spring	4	4	99.8	79.6	160.8	20.2**	.13	130.5	107.6	199.9	22.9**	.12
1944	Spring	5	4	129.0	109.4	172.6	19.6**	.11	170.8	144.2	210.7	26.6**	.13
1945	Spring	6	5	123.5	86.6	188.1	36.9**	.20	163.0	117.0	265.4	46.0**	.17
1946	Spring	7	6	86.1	61.7	205.2	24.4**	.12	107.1	76.3	285.4	30.8**	.11
1947	Spring	8	..	111.7	....	....	....	...	132.2	....	....	....	...
1948	Spring	8 & 9	7	121.8	88.6	234.8	33.2**	.14	161.4	122.3	324.4	39.1**	.12
1949	Spring	9 & 10	8	130.6	75.8	251.6	54.8**	.22	175.1	114.2	362.7	60.9**	.17
Unweighted h^2 for all years and seasons								.17					.16

[a] Heritability estimate = (difference between lines)/(accumulated selection difference).

[b] Accumulated selection difference between lines. In calculating the mean of the selected parents, each parent's weight was taken as many times as that parent had offspring.

* Actual difference between lines, and hence h^2 also, significant at 5 percent level.

** Actual difference between lines, and hence h^2 also, significant at 1 percent level.

Rapid and Slow lines in table 3 and figure 1. The extreme season-to-season variability likely to be encountered in an experiment of this kind is amply illustrated. However, it is of particular interest that the two lines were similarly affected by environmental fluctuations and became more and more distinct for weight at 154 and 180 days of age as selection continued over the ten-year period.

Heritability estimates were calculated for each season in which both lines were present by dividing the actual mean difference between

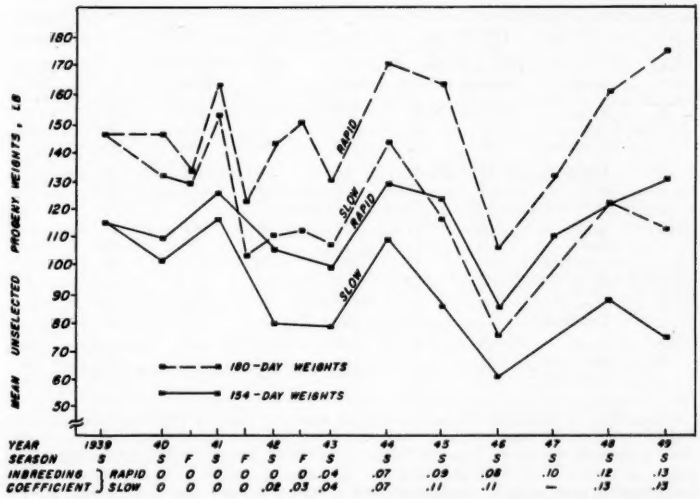


Figure 1. Mean unselected progeny weights of the Rapid and Slow Lines at 154 and 180 days of age.

lines in that season by the total amount of selection practiced up to that time. Lush (1948) has pointed out that if the first two generations are deleted for purposes of heritability estimation, in an experiment of this type, any epistatic deviations from the additive scheme will be nearly excluded and only additive genetic variation will then be important. These data suggest that such deviations must be unimportant in affecting 154- and 180-day weights since the first two generations of selection give estimates in almost exact agreement with those found in later generations. The unweighted mean heritabilities over all seasons are 0.17 and 0.16 for 154- and 180-day weights, respectively.

TABLE 3. WEIGHTS AT 154 AND 180 DAYS OF AGE IN THE RAPID AND SLOW LINES AND HERITABILITY (h^2) ESTIMATES BASED ON LINE DIFFERENCES [a]

Year	Season	Selection generation		154 days of age					180 days of age				
				Weights		Differences (R–S)			Weights		Differences (R–S)		
		Rapid	Slow	Rapid	Slow	Selected [b]	Actual	h^2	Rapid	Slow	Selected [b]	Actual	h^2
1939	Spring	0	0	115.6		....	....	...	147.2		....	....	...
1940	Spring	1	1	109.6	101.6	33.7	8.0	.24	147.0	132.2	52.4	14.8*	.28
1940	Fall	1	1	....	....	....	....	...	134.0	129.4	53.4	4.6	.09
1941	Spring	2	2	125.6	117.4	73.2	8.2	.11	163.1	153.2	105.8	9.9	.09
1941	Fall	2	2	....	....	....	....	...	122.6	103.9	104.5	18.7	.18
1942	Spring	3	3	106.3	80.2	111.9	26.1**	.23	143.7	110.4	152.9	33.3**	.22
1942	Fall	3	3	....	....	....	....	...	150.9	112.5	136.7	38.4**	.28
1943	Spring	4	4	99.8	79.6	160.8	20.2**	.13	130.5	107.6	199.9	22.9**	.12
1944	Spring	5	4	129.0	109.4	172.6	19.6**	.11	170.8	144.2	210.7	26.6**	.13
1945	Spring	6	5	123.5	86.6	188.1	36.9**	.20	163.0	117.0	265.4	46.0**	.17
1946	Spring	7	6	86.1	61.7	205.2	24.4**	.12	107.1	76.3	285.4	30.8**	.11
1947	Spring	8	..	111.7	....	....	....	...	132.2	....	....	....	...
1948	Spring	8 & 9	7	121.8	88.6	234.8	33.2**	.14	161.4	122.3	324.4	39.1**	.12
1949	Spring	9 & 10	8	130.6	75.8	251.6	54.8**	.22	175.1	114.2	362.7	60.9**	.17
Unweighted h^2 for all years and seasons								.17					.16

[a] Heritability estimate = (difference between lines)/(accumulated selection difference).

[b] Accumulated selection difference between lines. In calculating the mean of the selected parents, each parent's weight was taken as many times as that parent had offspring.

* Actual difference between lines, and hence h^2 also, significant at 5 percent level.

** Actual difference between lines, and hence h^2 also, significant at 1 percent level.

Rapid and Slow lines in table 3 and figure 1. The extreme season-to-season variability likely to be encountered in an experiment of this kind is amply illustrated. However, it is of particular interest that the two lines were similarly affected by environmental fluctuations and became more and more distinct for weight at 154 and 180 days of age as selection continued over the ten-year period.

Heritability estimates were calculated for each season in which both lines were present by dividing the actual mean difference between

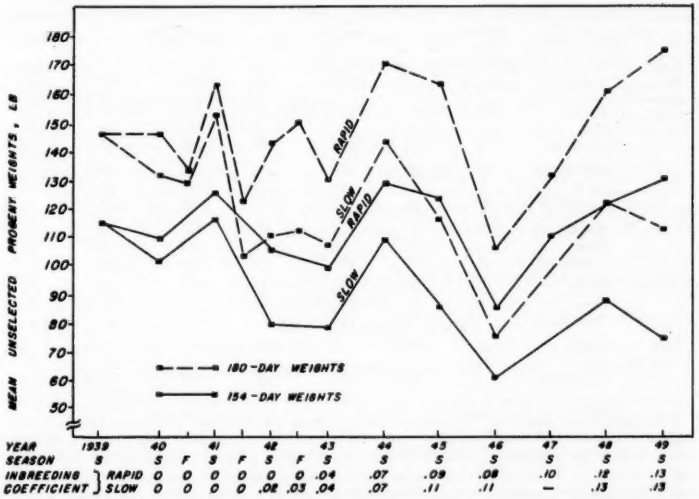


Figure 1. Mean unselected progeny weights of the Rapid and Slow Lines at 154 and 180 days of age.

lines in that season by the total amount of selection practiced up to that time. Lush (1948) has pointed out that if the first two generations are deleted for purposes of heritability estimation, in an experiment of this type, any epistatic deviations from the additive scheme will be nearly excluded and only additive genetic variation will then be important. These data suggest that such deviations must be unimportant in affecting 154- and 180-day weights since the first two generations of selection give estimates in almost exact agreement with those found in later generations. The unweighted mean heritabilities over all seasons are 0.17 and 0.16 for 154- and 180-day weights, respectively.

Regression of Offspring on Dam and on Mean of Parents. Estimates of heritability were calculated from intrasire regressions of progeny on dam and from regressions of progeny on mean of parents, within line, year-generation and season, table 4. In calculating the regressions, each

TABLE 4. HERITABILITY ESTIMATES OF INDIVIDUAL DIFFERENCES (h^2) FOR WEIGHT AT FIVE AGES BASED ON INTRASIRE REGRESSION OF LITTER MEAN ON DAM ($b_{\bar{L}.D}$) OR OF LITTER MEAN ON MEAN OF PARENTS ($b_{\bar{L}.\bar{P}}$) WITHIN LINE, YEAR-GENERATION AND SEASON

Age, days	Lines	No. of year-generation-seasons	$b_{\bar{L}.D}$ [a]			$b_{\bar{L}.\bar{P}}$ [b]		
			No. of sires	No. of litters	h^2	No. of litters	h^2	Mean h^2
0	Rapid	13	47	123	.12	133	.08	.10
	Slow	10	36	97	.01	107	.08	.05
	Combined [c]	23	83	220	.06	240	.08	.07
21	Rapid	11	34	83	.09	95	—.04	.03
	Slow	9	31	79	.18	89	—.04	.07
	Combined [c]	20	65	162	.14	184	—.04	.05
56	Rapid	13	43	108	.07	121	.04	.06
	Slow	10	35	88	.08	98	—.08	.00
	Combined [c]	23	78	196	.08	219	—.02	.03
154	Rapid	12	41	102	.33	115	.15*	.24
	Slow	9	32	84	.07	92	—.06	.01
	Combined [c]	21	73	186	.23	207	.09	.16
180	Rapid	15	47	115	.18	133	.33**	.26
	Slow	11	37	94	—.06	105	.10	.02
	Combined [c]	26	84	209	.05	238	.22**	.14

[a] Heritability of individual differences estimated from the formula: $h^2 = b_{\bar{L}.D}/[abnp(1+m)]$, derived by means of path diagrams, where ab = genetic contribution from dam to offspring (½); n = mean litter size; p = contribution of individual progeny weight to the mean litter weight or $1/\sqrt{n[1+(n-1)r]}$, when r is the intra-class phenotypic correlation between littermates obtained from variance components (table 6) and m = mean genetic relationship between sire and dam.

[b] Heritability of individual differences estimated from the formula: $h^2 = b_{\bar{L}.\bar{P}}/(p_1 pn)(1+m)$, derived by means of path diagrams, where p_1 = contribution of each parent independently to mean of parents and m, n and p are as indicated in footnote 1.

[c] Pooled regressions; hence, heritabilities are weighted.

* Significant at 5 percent level

** Significant at 1 percent level.

dam, or each mean of parents, was included as many times as there were individuals in the litter. This is equivalent to using the litter mean, weighted according to the number of pigs in the litter, as the dependent variable, thus yielding heritabilities on a family basis. Since most heritabilities are used on an individual basis, the family estimates were converted accordingly. In only a few cases were the regressions, and hence the heritabilities based upon them, significant. The estimates of heritability obtained by these two methods were used in obtaining a

TABLE 5. ANALYSIS OF VARIANCE WITHIN LINE, YEAR-GENERATION, AND SEASON, FOR WEIGHT AT FIVE AGES

A. Mean squares

Source of variation	Age, days: 0 D/F	0 M.S.	21 D/F	21 M.S.	56 D/F	56 M.S.	154 D/F	154 M.S.	180 D/F	180 M.S.
Sire progenies	97	1.16	88	16.9*	95	137.3*	72	1467	87	2751*
Litters of same sire	164	0.81*	130	11.9*	143	99.5*	113	1084**	125	1543*
Littermates	1748	0.16	1176	2.8	1180	24.4	750	387	847	571

B. Expected composition of mean squares [a]

Source of variation	Components	Meaning of Symbols
Sire progenies	$A + \bar{l}'L + \bar{s}S$	S = sire variance, $\bar{s}$ = number of times S enters mean square, $\bar{l}'$ = number of times L enters mean square
Litters of same sire	$A + \bar{l}\,L$	L = litter variance, $\bar{l}$ = number of times L enters mean square
Littermates	A	A = intra-litter variance

C. Expected components in terms of genetic and environmental variance [a]

General terms	Meaning of symbols
$S = \frac{1 + f' - 2f}{4} V(G)$	f = mean parental inbreeding coefficient f′ = mean progeny inbreeding coefficient V(G) = variance due mainly to additive gene differences among unrelated non-inbred pigs
$L = \frac{1 + f' - 2f}{4} [V(G) + 4V(G_m)] + V(E_m)$	V(M) [b] = non-heritable differences between litters due to differences between litters $V(E_m)$ and to heritable differences $V(G_m)$ between dams
$A = \frac{1 - f'}{2} V(G) + V(E)$	V(E) = non-heritable differences between littermates

* Significant at 5 percent level.
** Significant at 1 percent level.
[a] Components and coefficients of components from formulas developed by Dickerson (Dickerson, 1942; Hetzer, Dickerson and Zeller, 1944).
[b] V(M) could not be subdivided into $V(E_m)$ and $V(G_m)$ in these data but contains 0.94 $V(G_m) + V(E_m)$, the $V(G_m)$ being slightly less than 1.0 because of inbreeding within lines.

mean heritability estimate for each line and for the combined data from both lines for each age.

There was excellent agreement between the mean combined heritability estimates obtained by regression and from estimates based on line differences, viz., 0.16 and 0.17 for 154-day weight and 0.14 and 0.16 for 180-day weight, respectively. From this close agreement, and remembering the freedom of line-difference estimates from epistatic effects, it again appears from these data that such deviations from the additive scheme for weights at these ages are negligible.

Variance Components. Genetic and non-genetic components of variance were estimated on a non-inbred basis from an analysis of variance of weights at each of the five ages, using methods developed by Dickerson (1942) and Hetzer, Dickerson and Zeller (1944), tables 5, 6 and 7.

TABLE 6. ESTIMATES OF INTRA-LITTER (A), LITTER (L) AND SIRE (S) VARIANCES FOR WEIGHTS AT FIVE AGES, AND OF (L+S)/(A+L+S), THE FULL-SIB INTRA-CLASS CORRELATIONS

Age, days	A	L	S	A+L+S	(L+S)/(A+L+S)
0	.160	.097	.018	.275	.42
21	2.83	1.64	0.34	4.81	.41
56	24.4	14.8	2.4	41.6	.41
154	387	164	25	576	.33
180	571	247	97	915	.38

Differences between sire progenies within line, year-generation and season were significant in most cases, so that the associated heritability estimates should also be considered significant. However, such estimates are likely to include larger errors than those from the other methods used since any error in the sire component of variance would be multiplied by a factor of 4.26 in estimating heritability. Any lack of contemporaneity among sire progenies would be expected to inflate the heritability estimates because of the inclusion of environmental fluctuations.

Genetic Correlations

As selection in this experiment was based solely on 150-, 154- or 180-day weights, any differences between lines for birth-, 21- or 56-day weights must have arisen from pleiotropic gene effects or from linkage of genes affecting weight at the different ages. There was no indication

TABLE 7. ABSOLUTE AND RELATIVE VARIANCES IN WEIGHTS AT FIVE AGES ATTRIBUTED TO HERITABLE AND NON-HERITABLE SOURCES OF VARIATION ON A NON-INBRED BASIS

	Heritable		Non-heritable				
			Between litters		Within litters		
Age, days	V(G)[a]	V(G) / Total V	V(M)[b]	V(M) / Total V	V(E)[c]	V(E) / Total V	Total V[d]
0	.077	.28	.079	.28	.123	.44	.279
21	1.45	.30	1.30	.27	2.13	.44	4.88
56	10.2	.24	12.4	.29	19.5	.46	42.1
154	107	.18	139	.24	336	.58	582
180	413	.44	150	.16	372	.40	935

[a] $V(G) = 4.26S$.
[b] $V(M) = L - S$, approximately correct but not adjusted to non-inbred equivalent since $V(G_m)$ and $V(E_m)$ could not be separated in these data (footnote 2, Table 5).
[c] $V(E) = A - 2.055S$.
[d] Total V = variance expected between unrelated, non-inbred pigs of the breed sampled $= V(G) + V(M) + V(E)$.

TABLE 8. DIFFERENCES IN WEIGHT AT FIVE AGES BETWEEN UNSELECTED PROGENIES OF THE RAPID AND SLOW LINES FROM DAMS OF THE SAME AGE [a]

Year [b]	Generation		Line differences at indicated ages, lb. (R–S)				
	Rapid	Slow	Birth	21 days	56 days	154 days	180 days
1940	1	1	.05	−.3	−1.0	8.0	14.8
1941	2	2	.10	.4	1.3	8.2	9.9
1942	3	3	.00	.5	2.4	26.1	33.3
1943	4	4	.18	...	3.6	20.2	22.9
1945	6	5	.11	.3	6.8	36.9	46.0
1946	7	6	−.07	.0	3.6	24.4	30.8
1948	8	7	−.04	1.9	3.0	29.7	33.5
1949	10	8	−.36	.3	5.3	41.6	49.8
Unweighted difference [c]			.00	.44*	3.13**	24.39**	30.13**

[a] Includes only seasons in which weights were taken at all ages, except for 1943 when 21-day weights were not obtained.

[b] Spring seasons only.

[c] Although interaction of line x year-seasons was significant only for 154-day weights, there appeared to be a real tendency for the lines to diverge over the ten-year period, so that interaction was presumed, in fact, to be present (except for birth weights). Under these conditions unweighted differences give unbiased estimates of real line differences (Snedecor, 1946).

* Approached 5 percent level of significance closely.

** Significant at 1 percent level.

of difference between lines in birth weights, but differences in 21-day and 56-day weights were nearly significant and highly significant, respectively, table 8.

Genetic correlations were calculated directly by Falconer's (1954) method as shown in table 9. Weights at both 154 and 180 days of age

TABLE 9. GENETIC CORRELATION ESTIMATES FOR WEIGHT AT VARIOUS AGES [a]

Unselected characteristics	Selected characteristics	
	154-day weight	180-day weight
Birth weight	0	0
21-day weight	.32	.33
56-day weight	.78	.80

[a] Genetic correlations obtained by Falconer's (1954) method, as follows:

$$r_{GG'} = \frac{\Delta G' h \sigma_P}{\Delta G h' \sigma_{P'}}$$

where $r_{GG'}$ = genetic correlation

$\Delta G, \Delta G'$ = genetic change in selected and unselected characteristics, respectively.

h, h' = square root of heritability for selected and unselected characteristics respectively.

$\sigma_P, \sigma_{P'}$ = square root of total variance among unrelated, non-inbred pigs of the breed sampled for selected and unselected characteristics respectively.

e.g. $r_{GG'}$ for 56-day and 154-day weights $= \dfrac{(3.13)\ (\sqrt{.16})\ (\sqrt{582})}{(24.39)\ (\sqrt{.06})\ (\sqrt{42.1})} = .78$

were considered as selected traits. This appears likely to introduce little error because these weights are highly correlated for individuals. Genetic change in weight was taken as the unweighted mean difference between unselected progeny of the two lines over the ten-year period, table 8. With one exception, these comparisons were restricted to those seasons in which weights were taken at all ages and for pigs produced by dams of the same age, i.e. by gilts or by sows. The 1943 data were also included even though 21-day weights were not taken in that year. Heritability was assumed to be 0.16 for 154- and 180-day weights (estimates from this study) and 0.06 for 21- and 56-day weights (estimates from this study and from the findings of other workers as summarized by Krider *et al.* (1946)). Phenotypic standard deviations for unrelated, non-inbred pigs of the breed sampled were estimated as square roots of total variances, table 7.

Discussion

The relatively heavier weights of boars as compared to gilts (about 3 percent at 154 and 180 days) found in this study are in good agreement with differences found between boars or barrows and gilts by other investigators (Crampton, 1941; Whatley, 1942; Comstock *et al.*, 1944; Miranda *et al.*, 1946). Adjustments for sex differences remove a portion of the variation in weights, thus allowing more precise estimates of the genetic difference between groups than would be obtained if sex differences were ignored.

Differences between mean 154- and 180-day progeny weights of the Rapid and Slow lines produced by selection on individual body weights indicate that additive genetic variation exists for these traits. There was no indication that selection had changed in effectiveness over the ten-year period studied.

The desirability of a control line in experiments of this type to decrease errors in interpretation due to time trends in environmental effects is indicated by the extreme season-to-season and year-to-year fluctuations observed (figure 1). Conclusions based on results in either line alone appear hazardous and would be greatly influenced by the date of termination of the experiment. Thus Dickerson (1952) and Craft (1953) may have been misled in assuming that the difference found between the lines as reported by Krider *et al.* (1946) on the first four generations was due primarily to decreased growth rate in the Slow line.

Although it might be expected that selection would be more effective

in the Slow than in the Rapid line because of the many generations of selection presumably practiced for heavy weight for age in swine prior to the initiation of this experiment, there is no indication of such a situation in these data. Indeed, although not significant, it appears from the regression estimates of heritability, table 4, that a smaller amount of additive genetic variance was present in the Slow than in the Rapid line for weights at all ages except 21 days.

Heritability estimates in the neighborhood of 0.16 for weight or gains to 5 or 6 months of age found in this study by the more reliable methods are in fair agreement with recent values obtained by other investigators in other breeds and among crossbred animals. Thus Bernard *et al.* (1954) obtained a value of 0.10 for 154-day weight from their extensive data on several breeds and crossbreds, and an estimate of 0.20 from a survey of other studies. Cockerham (1952) obtained an estimate of 0.07 from a large amount of data on inbred lines of the Poland-China and Landrace breeds, while Blunn *et al.* (1953) calculated heritability estimates of 0.28 and 0.08 from regression technique for gains from 56 to 112 and 112 to 154 days, respectively, using data on inbred Duroc lines and crosses of four breeds.

Genetic correlation estimates obtained from this study indicate that indirect selection for heavy weights at 5 or 6 months of age based on weights at birth, 21 or 56 days of age, should be approximately 0, 20 or 50 percent as effective, respectively, as direct selection, e.g., correlation of 56-day weight and genotype for 154-day weight $= (\sqrt{0.06})$ $(0.78) = 0.19$ as compared to the correlation of 154-day weight and genotype $= (\sqrt{0.16}) = 0.40$.

It has been estimated by Blunn *et al.* (1953) that gains from 56 to 112 days of age are more highly heritable than those from zero to 56 days, and by Blunn, Warwick and Wiley (1954) that pre-weaning gains are only moderately associated with post-weaning gains. The findings of this experiment are in agreement with their results. They point out that boars castrated at 112 days of age can be marketed "satisfactorily" at market weight, which they reach at the same time as other stock. Some such scheme of delayed castration would appear to have considerable value in allowing more efficient selection for growth rate without sacrificing market quality among culled boars. Fast-growing females should also be selected on the basis of post-weaning gain or on weight at ages near market weight, as indicated by the results of this and other experiments.

Summary

The results of a ten-year experiment involving ten generations of selection for heavy weights and eight generations of selection for light weights at 154 and 180 days of age in Hampshire swine are presented. A total of 2036 pigs from 288 litters in 124 sire groups are included. Rapid and Slow lines derived from a sample of the breed and maintained as closed herds became more and more distinct for 154- and 180-day weight as selection continued over the entire period.

Heritability estimates for 154- and 180-day weights of 0.17 and 0.16 were obtained on the basis of line difference produced as compared to selection pressure exerted. Selection was as effective in separating the lines in later generations as in the first two, indicating the absence of important epistatic deviations from the additive scheme for these traits. Estimates based on regression of offspring on mean of parents and on intrasire regression of offspring on dam were combined and found to be 0.16 and 0.14 for 154- and 180-day weights, respectively. The less reliable method based on variance components gave heritability estimates of 0.18 and 0.44 for 154- and 180-day weights, respectively.

Heritability estimates for birth-, 21- and 56-day weights of 0.07, 0.05 and 0.03, respectively, were obtained from combined regression values, while estimates of 0.28, 0.30 and 0.24 were obtained from variance components, respectively.

Sex differences in weight were analyzed and boars were found to be significantly heavier than gilts by about 5 percent at birth and by about 3 percent at 21, 56, 154 and 180 days of age.

Genetic correlations were estimated on the basis of weight differences produced between lines at birth, 21 and 56 days of age, by selection based solely on weights at 150, 154 or 180 days of age. It appeared from the size of the genetic correlations and the more reliable heritability estimates obtained in this study that indirect selection for heavy weights at 154 or 180 days of age on the basis of birth-, 21- or 56-day weights would be approximately 0, 20 or 50 percent as effective, respectively, as direct selection for heavy 154- or 180-day weights.

Literature Cited

Baird, D. M., A. V. Nalbandov and H. W. Norton. 1952. Some physiological causes of genetically different rates of growth in swine. JOURNAL OF ANIMAL SCIENCE 11:292.

Bernard, C. S., A. B. Chapman and R. H. Grummer. 1954. Selection of pigs under farm conditions: kind and amount practiced and a recommended selection index. JOURNAL OF ANIMAL SCIENCE 13:389.

Blunn, C. T., G. N. Baker and L. E. Hanson. 1953. Heritability of gain in different growth periods in swine. JOURNAL OF ANIMAL SCIENCE 12:39.

Blunn, C. T., E. J. Warwick and J. R. Wiley. 1954. Interrelationships of swine weights at three ages. JOURNAL OF ANIMAL SCIENCE 13:383.

Cockerham, C. C. 1952. Genetic covariation among characteristics of swine. JOURNAL OF ANIMAL SCIENCE 11:738.

Comstock, R. E., L. M. Winters and J. N. Cummings. 1944. The effect of sex on the development of the pig. III. Differences in growth rate between gilts and barrows by lines of breeding. JOURNAL OF ANIMAL SCIENCE 3:120.

Craft, W. A. 1953. Results of swine breeding research. U.S.D.A. Circ. 916.

Crampton, E. W. 1941. Protein-mineral-vitamin supplements to barley in market hog rations. Sci. Agr. 21:613.

Dickerson, G. E. 1942. Experimental design for testing inbred lines of swine. JOURNAL OF ANIMAL SCIENCE 1:326.

Dickerson, G. E. 1952. Heterosis. Chapter 21, Iowa State College Press, Ames, Iowa.

Dickerson, G. E. and J. C. Grimes. 1947. Effectiveness of selection for efficiency of gain in Duroc swine. JOURNAL OF ANIMAL SCIENCE 6:265.

Evvard, J. M., M. G. Snell, C. C. Culbertson and G. W. Snedecor. 1927. Correlations between daily gains and feed requirements of growing and fattening swine. Proc. Amer. Soc. An. Prod. 85.

Falconer, D. S. 1954. Validity of the theory of genetic correlation. An experimental test with mice. Jour. Heredity 45:42.

Hetzer, H. O., G. E. Dickerson and J. H. Zeller. 1944. Heritability of type in Poland China swine as evaluated by scoring. JOURNAL OF ANIMAL SCIENCE 3:390.

Krider, J. L., B. W. Fairbanks, W. E. Carroll and E. Roberts. 1946. Effectiveness of selecting for rapid and slow growth rate in Hampshire swine. JOURNAL OF ANIMAL SCIENCE 5:3.

Lush, J. L. 1936. Genetic aspects of the Danish system of progeny-testing swine. Iowa Agr. Exp. Sta. Res. Bul. 204.

Lush, J. L. 1948. Heritability of quantitative characters in farm animals. Eighth Int. Congr. Genetics Proc. 1948:356.

Miranda, R. M., C. C. Culbertson and J. L. Lush. 1946. Factors affecting rate of gain and their relation to allotment of pigs for feeding trials. JOURNAL OF ANIMAL SCIENCE 5:243.

Snedecor, G. W. 1946. Statistical methods. 4th ed. Iowa State College Press, Ames, Iowa.

Whatley, J. A., Jr. 1942. Influence of heredity and other factors on 180-day weight in Poland China swine. Jour. Agr. Res. 65:249.

Wright, S. 1922. Coefficients of inbreeding and relationship. Amer. Nat. 56:330.

CARCASS YIELDS AS RELATED TO LIVE HOG PROBES AT VARIOUS WEIGHTS AND LOCATIONS

H. O. Hetzer, J. H. Zeller and O. G. Hankins [1]

United States Department of Agriculture [2]

CARCASS value as measured by percentage preferred cuts [3] and percentage lean meat in hams has been shown to be significantly correlated with various scores and body dimensions (Phillips *et al.*, 1939; Bogart *et al.*, 1940; Hetzer *et al.*, 1950; Bratzler *et al.*, 1953). However, neither visual estimates nor individual body measurements have been found to be sufficiently accurate to warrant their general use in a swine improvement program.

Hazel and Kline (1952) have reported the use of a probing technique for measuring leanness and fatness on live hogs. Based on records for 96 hogs, these workers reported a correlation of —0.50 between percentage five primal cuts and the average of four live hog backfat measurements. The corresponding correlation involving the average of four carcass backfat measurements was —0.45. Using the same technique, but employing measurements at eight different locations, Hazel and Kline (1953) subsequently reported the locations behind the shoulder, over the loin and the top of the ham to have the greatest accuracy if used to measure fatness and leanness. De Pape and Whatley (1954), studying the accuracy of live hog probes involving 72 pigs, reported a correlation of —0.67 between percentage primal cuts and the average of six live hog backfat measurements.

The present paper presents the results of a study of the relationship between various carcass measurements and live hog backfat measurements at four weights and three locations.

Materials and Methods

The data studied came from 140 pigs fed in Record of Performance trials at the Agricultural Research Center, Beltsville, Maryland, during the fall and winter of 1952–53. The pigs were from seven inbred lines and included representatives of Landrace, Landrace-Chester White,

[1] Deceased.

[2] The authors wish to acknowledge their indebtedness to W. H. Peters for the computations.

[3] The term "preferred cuts" as used here is synonymous with the term primal cuts of other workers.

Landrace-Duroc, Landrace-Duroc-Hampshire, Yorkshire-Duroc-Landrace-Hampshire, Landrace-Large Black and Landrace-Poland China breeding. Generally four pigs of a litter were fed as a group and, whenever possible, one boar, one barrow and two gilts were chosen from each litter. Measurements on 45 boars, 30 barrows and 65 gilts were available for study, the number of pigs tested per line varying from 3 to 11 for boars, from 2 to 8 for barrows and from 6 to 15 for gilts. The average weight of boars fed out as barrows was 87.0±3.3 lb. when they were castrated at 98.4±0.3 days of age.

All pigs were self fed in dry lots with concrete floors from weaning to a final weight of about 225 lb. The ration consisted of ground yellow corn supplemented with a protein-mineral mixture and chlortetracycline. The mixture fed the first six weeks consisted of 70 percent corn and 30 percent supplement. During the second six-weeks period the ration was changed to 75 percent corn and 25 percent supplement. Beginning with the third period until the end of the feeding trial the ration contained 83 percent corn and 17 percent supplement. All pigs were kept without feed for 24 hours before slaughter.

Measurements of backfat thickness on the live pigs were taken to the nearest millimeter and converted to inches, using the probing technique as suggested by Hazel and Kline (1952). Briefly, small incisions were made with a scalpel through the skin over the pig's back and a narrow metal ruler was pressed through the layer of fat to the firm tissue underneath. The ruler was then withdrawn and the reading marked by a sliding metal clip. Three measurements were taken on each pig at each of four weights about 1.5 inches off the midline of the body as follows: (1) immediately behind the shoulders; (2) at the middle of the back; and (3) at the middle of the loin. The plan was to measure each pig at 150 lb. and again at 175, 200 and 225 lb. The average weights at which the pigs were actually measured were 150.6±0.3 lb., 175.7±0.3 lb., 199.9±0.3 lb. and 224.1±0.3 lb.

Slaughtering and cutting were done in accordance with methods described by Hankins and Hiner (1937) and Hiner (1949). After chilling at 36–38° F. for approximately 72 hours, the carcasses were measured for backfat thickness at the first and seventh thoracic vertebrae and at the first, middle and last lumbar vertebrae. The carcasses were then separated into a full cut head, two-rib picnic shoulders, butts, plates, square cut unskinned hams, loins with an average of one-fourth inch of fat left on, and bellies trimmed just above the teat line and squared at the shoulders, back and flank ends. The right ham of each

hog was separated into lean, fat, bone and skin. All cuts were weighed to the nearest one-tenth pound and the yield of each cut was computed as a percentage of the live weight at slaughter.

The carcass items studied were (1) average of the five backfat measurements, (2) dressing percentage as measured by chilled carcass weight, (3) percentage preferred cuts as measured by the combined yield of hams, loins, bacons, picnic shoulders and shoulder butts, (4) percentage fat cuts as measured by the combined yield of backfat, leaf fat, plates and cutting fat, and (5) percentage lean meat in hams as measured by doubling the yield of lean meat in the right ham.

TABLE 1. MEANS AND STANDARD ERRORS OF VARIABLES FOR 45 BOARS, 30 BARROWS AND 65 GILTS [a]

Variable	Boars		Barrows		Gilts	
	Mean	Standard error	Mean	Standard error	Mean	Standard error
Age at slaughter—days	182.9	3.2	183.1	3.6	191.2	2.6
Live weight at slaughter, lb.	212.0	0.74	210.7	0.85	212.9	0.61
Average of 3 live hog backfat measurements at						
150 lb.—inches	1.08	0.02	1.14	0.02	1.19	0.02
175 " "	1.17	0.02	1.29	0.02	1.28	0.02
200 " "	1.28	0.02	1.39	0.02	1.41	0.02
225 " "	1.40	0.02	1.57	0.03	1.50	0.02
Average of 5 carcass backfat measurements—inches	1.37	0.03	1.57	0.03	1.55	0.02
Yields as percentage of slaughter weight:						
Chilled carcass—percent	79.5	0.22	80.7	0.26	81.6	0.18
Preferred cuts — "	51.6	0.20	51.2	0.23	52.4	0.16
Fat " — "	11.0	0.28	13.1	0.32	13.2	0.23
Lean meat in hams	9.3	0.11	8.7	0.12	9.2	0.09

[a] Computed by the method of Least Squares as suggested by Walter R. Harvey (personal communication).

Results and Discussion

Table 1 shows the means with their standard errors for the various items studied. The average weight of the pigs decreased by about 13 lb. from the time they were taken off test to the time they were slaughtered, the slaughter weight for the three sex groups averaging 211.9 lb. The sex differences in slaughter weight were quite small, but gilts were about eight days older at time of slaughter than both boars and barrows. In backfat thickness on the live animal, barrows exceeded boars significantly at 175, 200 and 225 lb. Backfat thickness was less in barrows than in gilts at 150 and 175 lb. but barrows exceeded gilts at 200 and particularly at 225 lb. Thickness of backfat in gilts, in turn, was significantly greater at each of the four weights than in boars.

The linear intra-line regressions of thickness of backfat on body weight are shown in figure 1. The regressions were positive and highly significant for all three sex groups, indicating that for each 10-lb. increase in body weight thickness of backfat would be expected to increase by an average of 0.044, 0.057 and 0.042 inches in boars, barrows and gilts, respectively. There was practically no difference in the slopes of the regressions for boars and gilts, but barrows significantly exceeded boars and gilts in rate of fat deposition. The increase in back-

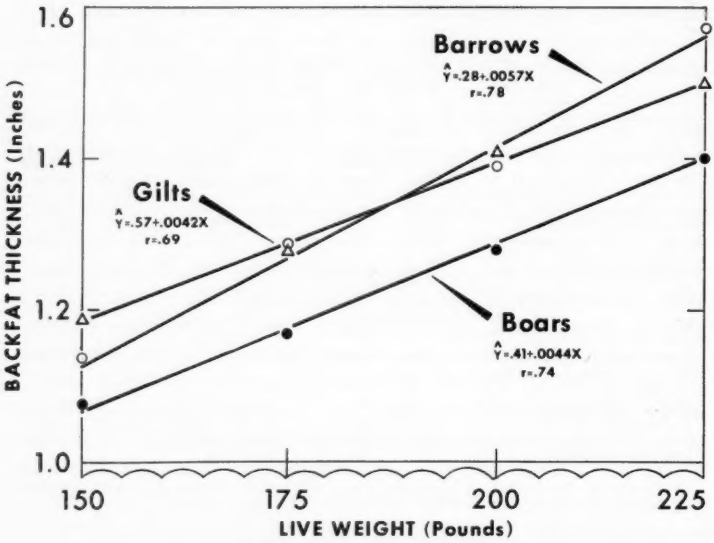


Figure 1. Intra-line regressions of live hog backfat measurements (Y) on body weight (X) in boars (dots), barrows (circles) and gilts (triangles).

fat thickness between 150 and 225 lb. averaged 0.32 inches in boars, 0.43 inches in barrows and 0.31 inches in gilts.

The corresponding intra-line correlations between the average of the live hog backfat measurements and body weight were 0.74, 0.78 and 0.69, respectively.

The data concerning the carcass items in table 1 show that the sex differences in the average of the five carcass backfat measurements are consistent with those observed for the live hog measurements at 225 lb., although when compared with the latter, the carcass backfat

measurements averaged slightly higher in gilts, slightly lower in boars and equal in barrows. In dressing percentage, gilts ranked highest, followed by barrows and boars in that order. In yield of preferred cuts, gilts exceeded both barrows and boars, the difference in favor of gilts being 1.2 and 0.8 percent, respectively. Average yield of fat cuts was significantly lower in boars than in both barrows and gilts, there being practically no difference between the two latter groups. Yield of lean meat in hams, on the other hand, differed little between boars and gilts, both of which exceeded barrows by about 0.5 percent.

TABLE 2. INTRA-LINE CORRELATIONS BETWEEN LIVE HOG BACKFAT MEASUREMENTS ON THE SAME PIG AT FOUR WEIGHTS

Variable	Sex	Backfat thickness at—		
		175 pounds	200 pounds	225 pounds
Backfat thickness at 150 pounds	Boars	.64**	.49**	.17
	Barrows	.58**	.46*	.55**
	Gilts	.62**	.41**	.40**
	Average [a]	.62**	.44**	.37**
Backfat thickness at 175 pounds	Boars		.58**	.41**
	Barrows		.71**	.70**
	Gilts		.64**	.65**
	Average [a]		.62**	.58**
Backfat thickness at 200 pounds	Boars			.45**
	Barrows			.66**
	Gilts			.73**
	Average [a]			.64**

[a] Computed on intra-sex-and-line basis.
* Significant at 5 percent level.
** Significant at 1 percent level.

Accuracy of Live Hog Measurements

The accuracy of the live hog backfat measurements was examined by studying the correlations between the backfat measurements taken on the same pig at different weights. These correlations are shown in table 2.

Although considerable variation exists between some of the correlations, they were not consistently higher or lower in one sex group than in the other, and in no case did corresponding correlations for boars, barrows and gilts differ significantly. The results suggest, therefore, that the accuracy of the live hog measurements was not affected by the general sex difference in fatness. However, the correlations between

measurements taken at intervals of 25 lb. (i.e. at 150 and 175; 175 and 200; and 200 and 225 lb.) were generally higher than those between measurements taken at intervals of 50 lb. (i.e. at 150 and 200; and 175 and 225 lb.), while the latter in turn were generally higher than those between measurements at the 75-lb. interval from 150 to 225 lb. This is not especially surprising, since temporary and uncontrolled differences in the environment would tend to have a greater effect in decreasing the correlation between measurements taken at long as compared with short intervals. As concerns the relative accuracy of the

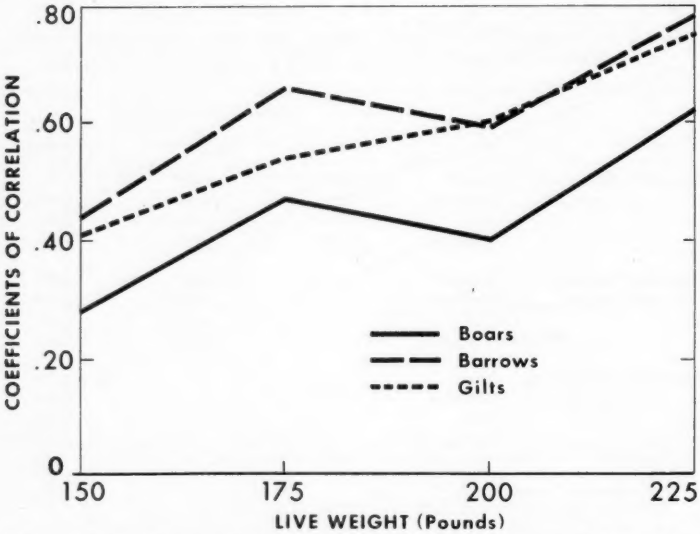


Figure 2. Intra-line correlations of carcass backfat thickness with live hog backfat measurements at four weights.

measurements at the several weights, it follows, therefore, that the nearer to the desired weight an animal is measured, the greater in general, is the accuracy of the measurement if used to estimate backfat thickness at that weight.

Correlations of Carcass Characteristics with Live Animal Measurements

The question whether the predictive value of live hog backfat measurements varies with the weight at which the animal is measured, that is, whether measurements taken during the growing period are as accurate indicators of carcass value as measurements at market weight,

was studied by computing the correlations between the various carcass characteristics and the average of the live hog measurements for the several weights. Correlations between the average of the carcass backfat measurements and the remaining carcass characteristics were also obtained to determine how the accuracy of live hog backfat measurements compared with that of carcass backfat measurements if used to estimate carcass yields. The correlations were computed for each sex group on a within-line basis, the correlations for the three sex groups combined in

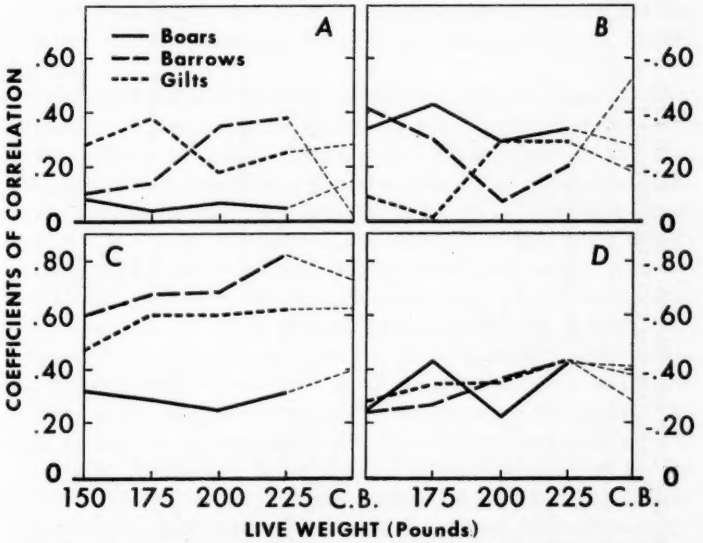


Figure 3. Intra-line correlations of live hog backfat measurements at four weights and thickness of backfat on carcass (c. b.) with dressing percentage (A), percentage preferred cuts (B), percentage fat cuts (C), and percentage lean meat in hams (D).

turn being computed on a within sex-and-line basis. In testing the significance of the difference between correlations having a variable in common, use was made of the method suggested by Hotelling (1940) as given by Hazel and Kline (1952).

Figure 2 shows for boars, barrows and gilts the correlations between the average of the five carcass backfat measurements and the average of the three live hog measurements at each of the four weights. Similarly, figures 3A to 3D show for each sex group the correlations of

TABLE 3. INTRA-SEX-AND-LINE CORRELATIONS OF CARCASS YIELDS WITH LIVE HOG BACKFAT MEASUREMENTS AND CARCASS BACKFAT THICKNESS

Variable	Live hog measurements at				Carcass backfat thickness
	150 lb.	175 lb.	200 lb.	225 lb.	
Carcass backfat thickness	.38**	.53**	.55**	.72**	
Dressing percentage	.17	.18*	.20*	.23*	.17
Percentage preferred cuts	−.24**	−.24**	−.22*	−.28**	−.29**
Percentage fat cuts	.42**	.47**	.48**	.54**	.54**
Percentage lean meat in hams	−.26**	−.35**	−.31**	−.42**	.33**

* Significant at 5 percent level.
** Significant at 1 percent level.

TABLE 4. INTRA-SEX-AND-LINE CORRELATIONS OF CARCASS YIELDS WITH INDIVIDUAL LIVE HOG BACKFAT MEASUREMENTS AT THREE LOCATIONS AND TWO WEIGHTS

Variable	Live hog measurements at							
	175 lb.				225 lb.			
	Behind shoulder	Middle of back	Middle of loin	Average	Behind shoulder	Middle of back	Middle of loin	Average
Dressing percentage	.30**	−.01	.08	.18*	.15	.06	.33**	.23*
Percentage preferred cuts	−.03	−.32**	−.20*	−.24**	−.20*	−.34**	−.12	−.28**
Percentage fat cuts	.35**	.34**	.35**	.47**	.36**	.41**	.50**	.54**
Percentage lean meat in hams	−.17	−.35**	−.27**	−.35**	−.27**	−.31**	−.40**	−.42**

* Significant at 5 percent level.
** Significant at 1 percent level.

dressing percentage, percentage preferred cuts, percentage fat cuts and percentage lean meat in hams with the average of the three live hog backfat measurements and with the average backfat thickness on the carcass. Table 3 shows the corresponding intra-sex-and-line correlations, while the intra-sex-and-line correlations involving the individual live hog measurements at the 175 and 225 lb. weights and the same four carcass measurements are given in table 4. It should be noted here that except for the correlations between the backfat measurements behind the shoulder and percentage fat cuts, none of the corresponding correlations involving the individual live hog measurements at the different locations differed significantly between sex groups and hence are not included.

Carcass Backfat Thickness. All of the correlations between thickness of backfat on the carcass and the live hog backfat measurements were positive (figure 2, table 3), as might be expected since the two variables are different measures of the same trait. All of these correlations, except the one involving measurements at 150 lb. in boars were significant. As the results in figure 2 and table 3 show, there was a definite upward trend in the correlations with increased body weight. This was true for all sex groups, the correlations involving measurements taken at 150 and again at 225 lb. increasing from 0.28 to 0.62 in boars, from 0.44 to 0.78 in barrows and from 0.41 to 0.75 in gilts. Although the correlations in boars were lower at all weights than those in barrows or gilts, none of the differences among corresponding correlations were large enough to be significant. The intra-breed correlations of 0.81 reported by Hazel and Kline (1952) between the average backfat thickness on the carcass and the average of four live hog backfat measurements agrees rather well with the present intra-line-and-sex-correlation of 0.72 between average thickness of carcass backfat and the average of the three live hog measurements at 225 lb.

Dressing Percentage. The correlations of dressing percentage with the average of the live hog measurements at the several weights were positive but generally small, varying from 0.05 to 0.08 in boars, from 0.10 to 0.38 in barrows and from 0.18 to 0.38 in gilts (figure 3). Only the correlations involving measurements at 150, 175 and 225 lb. in gilts were significant but none of these correlations differed significantly from the corresponding ones in boars or barrows. Taken at face value, the correlations in barrows suggest a gradual increase in accuracy of live hog backfat measurements with increasing body weight, whereas no such trend is evident in boars or gilts. The intra-sex-and-line cor-

relations point in the same direction as the correlations in barrows, but are considerably more uniform, varying only from 0.17 to 0.23 (table 3). These results suggest that live hog backfat measurements have relatively low accuracy for predicting dressing percentage and that any increase in their accuracy with increasing body weight is too slight to be important. Nevertheless, live hog backfat measurements taken at 225 lb. appear to be as accurate measures of dressing percentage as are carcass backfat measurements, the respective intra-sex-and-line correlations being 0.23 and 0.17 (table 3).

A comparison between the correlations involving the individual live hog measurements in table 4 shows that if measured at 175 lb., the location immediately behind the shoulder is significantly more accurate as a measure of dressing percentage than either the middle of the back or the middle of the loin, whereas at 225 lb. the latter is the more accurate location. Interestingly, the location behind the shoulder at 175 lb. and the middle of the loin at 225 lb. appear to be more accurate measures of dressing percentage than the respective averages of the three live hog measurements at those weights. At both 175 and 225 lb. the middle of the back seems worthless for measuring dressing percentage.

Percentage Preferred Cuts. All of the correlations involving percentage preferred cuts with the live hog and the carcass backfat measurements were negative (figure 3, table 3) indicating that the greater the depth of backfat, the lower in general was the yield of preferred cuts. The correlations were generally higher in boars than in barrows or gilts, but none of the differences among corresponding correlations were large enough to be significant. Although considerable variation exists between some of the correlations involving measurements at the different weights, they show no definite upward trend with increasing body weight, the intra-sex-and-line correlations increasing only from —0.24 for measurements taken at 150 lb. to —0.28 for measurements taken at 225 lb. It seems, therefore, that any increase in the predictive value of live hog backfat measurements with increasing body weights is too small to be important if these measurements are used to measure yield of preferred cuts.

Barrows showed a significantly higher correlation of percentage preferred cuts with carcass backfat thickness than with the live hog measurements at both 225 and 200 lb. (figure 3), but none of the differences between the corresponding correlations in boars or gilts or between the intra-sex-and-line correlations were significant. Thus, with

the possible exception of barrows, measurements of backfat thickness on the live hog seem to be as accurate for predicting percentage preferred cuts as are measurements of backfat thickness on the carcass.

Table 4 shows that at both the 175- and 225-lb. weights, the measurements over the middle of the back gave higher correlations with percentage preferred cuts than those taken at the other two locations. At 175 lb. the correlation involving that location was significantly larger than the one involving the location behind the shoulder, whereas at 225 lb. it differed significantly only from the one involving the middle of the loin, there being no significant difference between any of the other correlations. A point of interest here is that the present intra-sex-and-line correlations of —0.28 between the average of the live hog backfat measurements at 225 lb. and percentage preferred cuts is substantially lower than the correlation of —0.50 reported between these variables by Hazel and Kline (1952). Also, these workers reported the locations behind the shoulder and at the middle of the loin to be more accurate as indicators of percentage primal cuts, whereas in this study the location at the middle of the back appears to be most accurate.

Percentage Fat Cuts. All of the correlations between percentage fat cuts and the live hog backfat measurements were positive and highly significant for the most part (figure 3, table 3), indicating that the greater the amount of backfat the higher in general was the yield of fat cuts. There was a tendency for the accuracy of the measurements to increase with increasing body weight, the intra-sex-and-line correlation for measurements taken at 150 lb. being 0.42 as compared with 0.54 for measurements taken at 225 lb. The corresponding correlations for the three sex groups were 0.32 and 0.31 for boars, 0.60 and 0.82 for barrows and 0.47 and 0.62 for gilts. The correlations in barrows were higher at all weights than the corresponding ones in gilts, while all the correlations in gilts were higher than those in boars. However, only the differences observed among the correlations involving the measurements at 225 lb. were larger than could reasonably be attributed to mere chance.

A comparison of the correlations involving the live hog measurements with those involving thickness of backfat as measured in the carcass (table 3), indicates that the live hog measurements at 150, 175 and 200 lb. were slightly less accurate in estimating percentage fat than the carcass backfat measurements. However, there was no consistent tendency for the latter to be more accurate than live animal measurements taken at 225 lb., the intra-sex-and-line correlations actually being 0.54

in both cases. None of the correlations involving thickness of carcass backfat differed significantly from any of the corresponding correlations involving the live hog measurements at the different weights.

The correlations involving the individual live hog measurements and percentage fat cuts were practically identical for the measurements taken at 175 lb., while for the measurements taken at 225 lb., the correlations were less uniform, varying between 0.36 and 0.50 (table 4). When measured at 225 lb. the location at the middle of the loin had the highest accuracy for predicting percentage fat cuts, but none of the correlations obtained for the 225 lb. measurements differed significantly. At both 175 and 225 lb., the average of the three individual live hog measurements was a more accurate measure of percentage fat cuts than were the measurements at any one of the individual locations.

Percentage Lean Meat in Hams. All of the correlations between percentage lean meat in hams and the live hog backfat measurements were negative, but only those involving measurements taken at the 225-lb. weight were significant in all three sex groups (figure 3). The correlations in both barrows and gilts showed a gradual trend upward with increasing weight, whereas in boars the trend was actually down from 175 to 200 lb. However, none of the differences among corresponding correlations were significant, indicating that the apparent sex differences were probably the result of sampling errors. Because of the noticeably low correlation obtained in boars for the backfat measurements at 200 lb., the intra-sex-and-line correlations do not show as regular a trend as those in barrows or gilts. Even so, however, the intra-sex-and-line correlations increased from —0.26–0.42 for measurements taken at 150 and 225 lb., respectively (table 3).

The correlations involving thickness of carcass backfat measurements were smaller in all sex groups than the corresponding ones involving the live hog measurements at 225 lb. (figure 3). However, none of the corresponding differences were large enough to be significant. A similar situation was observed for the three sex groups on a combined basis, the intra-sex-and-line correlations involving live hog measurements at 225 lb. being —0.42 compared with —0.33 for the correlation involving measurements of backfat in the carcass.

The correlations involving the individual live hog measurements in table 4 show that at both the 175 and 225-lb. weights the measurements taken at the shoulder were lowest in accuracy for predicting percentage lean meat in hams, the respective correlations being —0.17 and —0.27. At 175 lb. the location at the middle of the back appeared to be most

accurate while at 225 lb. the middle of the loin gave the greatest accuracy. However, none of the corresponding correlations differed significantly, suggesting that there is no real advantage for any one location if used to measure lean meat in hams. At both 175 and 225 lb. the correlations involving the average of the three live hog measurements were as large or larger than those involving the best single location.

Summary

Measurements of backfat thickness were made on 140 pigs at each of four weights and three locations to determine their accuracy as criteria of carcass value. The measurements on the live pigs were taken at about 150, 175, 200 and 225 lb. approximately 1.5 inches off the midline of the body behind the shoulder, at the middle of the back, and at the middle of the loin. The pigs consisted of 45 boars, 30 barrows and 65 gilts representing seven inbred lines.

Thickness of backfat in barrows was intermediate between that in boars and gilts at 150 lb., but barrows laid on fat significantly faster until at 250 lb. they exceeded both boars and gilts. Gilts significantly exceeded boars in backfat thickness at all four weights.

The intra-sex-and-line correlation between the average of the live hog measurements and the average of the five carcass backfat measurements increased from 0.38 to 0.72 for measurements taken at 150 and 225 lb., respectively.

The averages of the live hog measurements showed significant negative correlations with percentage preferred cuts, but the accuracy of measurements taken at 225 lb. differed little from that of measurements taken at the lighter weights. The correlation between measurements at 225 lb. and percentage preferred cuts was —0.28. At both 175 and 225 lb. the location at the middle of the back was most accurate as a measure of yield of preferred cuts.

All of the correlations between percentage fat cuts and the live hog measurements were positive and significant. Measurements taken at 225 lb. appeared to be more accurate measures of yield of fat cuts than those at the lighter weights, the correlations involving measurements at 225 and 150 lb. being 0.54 and 0.42, respectively. The middle of the loin was the most accurate single location at 225 lb. for measuring percentage fat cuts.

All of the correlations between percentage lean meat in hams and the live hog measurements were negative and significant. They varied from —0.26 to —0.42 for measurements taken at 150 and 225 lb.,

respectively. At 225 lb. the location at the middle of the loin appeared to be the most accurate single criterion of leanness in hams.

While the live hog measurements studied do not show as much accuracy as criteria of carcass value as might be desired, the results suggest that when taken at weights between 175 and 225 lb. they are generally as accurate as are carcass backfat measurements. The results also suggest that live hog measurements have greater accuracy for measuring fatness than for measuring percentage preferred cuts or percentage lean meat in hams.

Literature Cited

Bogart, R., L. A. Weaver and J. E. Comfort. 1940. Carcass studies including scores, measurements and yields. Reg. Swine Br. Lab. Res. Item No. 17 (Mimeo).

Bratzler, L. J. and E. P. Margerum, Jr. 1953. The relationship between live hog scores and carcass measurements. JOURNAL OF ANIMAL SCIENCE 12:856.

De Pape, J. G. and J. A. Whatley, Jr. 1954. Live hog probes at various sites, weights and ages as indicators of carcass merit. JOURNAL OF ANIMAL SCIENCE 13:957.

Hankins, O. G. and R. L. Hiner. 1937. A progress report on the meat yields of Danish Landrace hogs in comparison with certain American breeds. Am. Soc. Anim. Prod., Proc. 255.

Hazel, L. N. and E. A. Kline. 1952. Mechanical measurement of fatness and carcass value on live hogs. JOURNAL OF ANIMAL SCIENCE 11:313.

Hazel, L. N. and E. A. Kline. 1953. Accuracy of eight sites for probing live pigs to measure fatness and leanness. JOURNAL OF ANIMAL SCIENCE 12:894.

Hetzer, H. O., O. G. Hankins, J. X. King and J. H. Zeller. 1950. Relationship between certain body measurements and carcass characteristics in swine. JOURNAL OF ANIMAL SCIENCE 9:37.

Hiner, R. L. 1949. Standard method of cutting pork carcasses for determining the yield and percentage of wholesale cuts. Second Ann. Reciprocal Meat Conf., Proc., p. 123.

Hotelling, Harold. 1940. Selection of variates for use in prediction with some comments on the problem of nuisance parameters. Ann. Math. Stat. 11(3):271.

Phillips, R. W., H. O. Hetzer and R. L. Hiner. 1939. Relation of scores of swine to carcass yields and certain carcass measurements. Reg. Swine Br. Lab. Res. Item No. 15 (Mimeo.).

THE INTERACTION OF TEMPERATURE AND THIOURACIL FEEDING UPON CARCASS CHARACTERISTICS AND FEEDING CHARACTERISTICS OF PIGS

E. F. JOHNSTON, N. R. ELLIS AND C. F. WINCHESTER

U. S. Department of Agriculture

MUCH of the swine research during the last several years has been directed toward producing a leaner hog without sacrificing rate of gain or feed efficiency. A great deal of this work has been done from the genetic or nutritional angle. It is becoming obvious that neither of these approaches within itself can give complete success. A genetic bacon-type hog can be made fat by injudicious feeding. Also a genetically fat-type hog can be made leaner by proper nutrition. Many of the attempts to produce leaner hogs by either of these methods have met with some success as far as leanness is concerned but generally have also resulted in a lowering of rate of gain and feed efficiency. It was felt that the interaction of these two factors and also other factors in the environment should be studied. It is well known that fat deposition and growth rate are influenced strongly by the endocrine glands. These glands in turn are influenced by genetics, nutrition, light in some cases, temperature, and possibly other factors. This experiment was designed to study the interaction of temperature and the feeding of a goitrogen (thiouracil) upon carcass characteristics and upon rate of gain and feed efficiency.

Methods and Materials

The pigs used in these trials were not necessarily of similar breeding but no attempt was made to secure pigs of diverse breeding. Most of them were pigs from inbred lines produced at the Agricultural Research Center, Beltsville, Md. They were barrows and gilts, each sex being equally divided within treatments between control and treated pens.

The data from five trials form the basis of this paper. For each trial, 12 pigs were placed in each of two temperature chambers and were individually fed. Six pigs in each chamber were controls and six were treated with thiouracil. In trials 1 and 2 the temperatures were not as well controlled as in trials 3, 4, and 5. In trial 1 the temperature in the "cool" chamber varied between 50° and 60° F., and in the "hot"

chamber between 74° and 84° F. In trial 2 the temperature in the cool chamber varied between 45° and 68° F. and that in the "hot" chamber between 76° and 90° F. In trials 3, 4, and 5 the temperature in the "cool" chamber was 50° ±2° F., and that in the "hot" chamber was 90° ±2° F.

The initial weights when the pigs were placed on test were very similar for the treated and untreated pigs within trials at each temperature. Trials 1, 3, 4, and 5 were treated as replicates in the analysis because initial weights in all cases were above 150 lb.

Trial 2 differed from the others in that treatment was started at a younger age and a smaller weight. This trial was treated separately in the analysis, because previous work had shown that young pigs treated with thiouracil gave different results from older pigs in rate of gain and feed efficiency.

Treatment with thiouracil was at the rate of 0.15 percent of the ration. The lengths of the treatment periods were: Trial I, 28 days, trial II, 32 days; trial III, 28 days; trial IV, 26 days; and trial V, 28 days.

The characteristic which was of most interest in this study was carcass composition and the effect of treatment on the ratio of lean meat to fat as measured by (1) thickness of backfat (2) percentage of fat, protein, and water in the hams and (3) ratio of mechanically separable lean meat to fat in the hams.

The backfat thickness was measured at slaughter and the components of the hams were determined by physical separation and chemical analysis.

Rate of growth and feed efficiency are also of interest from a practical standpoint.

All groups were fed the same ration except that treated groups had the thiouracil added. There was some limitation of feed in the thiouracil fed group in the "cold" chamber so that rate of gain in the treated and control chambers would be similar.

Results

Results of Trials I and III are summarized in table 1, those of Trials IV and V in table 2, and those of Trial II in table 3.

It will be noticed that the numbers of pigs in Trials III, IV, and V are not the same. This was due to sickness and deaths. Apparently much of the trouble was due to pneumonia. Since these cases of illness

TABLE 1. EFFECT OF THIOURACIL, MODIFIED BY ENVIRONMENTAL TEMPERATURE ON RATE AND EFFICIENCY OF GAINS AND CARCASS COMPOSITION OF SWINE

Trial No.	I				III			
Days on test	28				28			
Environmental temperature, ° F.	50–60 58		74–84 80		50		90	
Ration fed as dry mash (Experimental ration contained 0.15% thiouracil)	Control	Thiouracil	Control	Thiouracil	Control	Thiouracil	Control	Thiouracil
No. of pigs	6	6	6	6	4	4	6	6
Initial weight, mean, lb.	180	182	185	189	166	166	167	166
Final weight, mean, lb.	231	236	229	228	210	214	216	211
Feed per pig, mean, lb.	6.84	5.72	7.38	5.59	1.57	1.71	1.75	1.61
Daily gain, mean, lb.	1.82	1.93	1.57	1.39	7.56	6.53	6.81	5.97
Feed per pound gain, mean, lb.	3.8	3.0	4.7	4.0	4.8	3.8	3.9	3.7
Physical and Chemical Composition of Carcasses (Means)								
Thyroid size, gm.[a]	10.8	22.3	19.6	22.5	12.4	17.1	14.9	16.5
Liver size, lb.[a]	2.9	3.5	3.1	3.3	3.6	3.8	3.2	3.6
Ratio lean to fat, (mechanically separated) in ham	1.961	2.190	2.043	2.261	1.769	2.278	1.958	2.174
Thickness of back fat, mean, mm.	48.2	43.7	45.0	46.5	41.0	37.2	36.8	37.3
Ham, total edible portion, Composition, percent								
Water	51.9	55.8	53.2	54.6	48.7	54.2	52.3	54.1
Fat	32.8	28.5	31.0	28.9	35.6	28.8	31.7	29.9
Protein	15.2	15.6	15.4	15.3	14.8	16.3	15.1	15.4
Body temperature, F.	103.0	102.6	103.8	103.4	103.4	103.0	104.4	103.8

[a] Adjusted to body weight of 220 lb.

TABLE 2. EFFECT OF THIOURACIL, MODIFIED BY ENVIRONMENTAL TEMPERATURE ON RATE AND EFFICIENCY OF GAINS AND CARCASS COMPOSITION OF SWINE

Trial No.	IV				V			
Days on test	26				28			
Environmental temperature, ° F.	50		90		50		90	
Ration fed as dry mash (Experimental ration contained 0.15% thiouracil)	Control	Thiouracil	Control	Thiouracil	Control	Thiouracil	Control	Thiouracil
No. of pigs	5	4	5	6	4	4	6	6
Initial weight, mean, lb.	194	184	194	190	183	174	168	168
Final weight, mean, lb.	227	224	234	230	226	217	191	182
Feed per pig, mean, lb.	6.38	6.18	6.30	6.53	1.54	1.54	0.82	0.50
Daily gain, mean, lb.	1.27	1.54	1.54	1.54	6.66	5.93	4.17	3.42
Feed per pound gain, mean. lb.	5.0	4.0	4.1	4.2	4.3	3.8	5.1	6.8
Physical and Chemical Composition of Carcasses (Means)								
Thyroid size, gm.[a]	7.3	12.4	10.0	12.1	12.2	18.4	12.4	17.1
Liver size, lb.[a]	2.9	3.8	3.6	3.8	2.8	3.4	2.9	3.0
Ratio lean to fat (mechanically separated) in ham	1.592	2.160	1.956	1.961	2.185	2.630	2.594	2.465
Thickness of back fat, mean, mm.	41.2	32.5	41.4	41.4	38.5	35.5	35.0	34.2
Ham, total edible portion, Composition, percent								
Water	49.1	52.8	51.2	52.6	53.3	56.3	55.6	55.2
Fat	35.6	31.3	33.1	31.6	30.6	27.0	27.7	28.2
Protein	14.5	15.0	15.0	15.2	15.7	16.3	16.1	16.0
Body temperature, F.	103.1	102.5	103.3	103.2	102.8	102.1	103.2	103.2

[a] Adjusted to body weight of 220 lb.

or death were mostly in the "cool" chamber, it is possible that they might have been caused in part by the temperature. There is no indication that these deaths were caused by the thiouracil. Temperature alone may not have caused the trouble but the method of producing the temperature may have led to such disorders as pneumonia and related respiratory disorders.

TABLE 3. EFFECT OF THIOURACIL, MODIFIED BY ENVIRONMENTAL TEMPERATURE ON RATE AND EFFICIENCY OF GAINS AND CARCASS COMPOSITION OF SWINE

Trial No.	II			
Days on test	32			
Environmental temperature, °F.	45–68 58		76–90 80	
Ration fed as dry mash (Experimental ration contained 0.15% thiouracil)	Control	Thiouracil	Control	Thiouracil
No. of pigs	6	6	6	6
Initial weight, mean, lb.	72	72	72	72
Final weight, mean, lb.	99	94	111	112
Daily gain, lb.	0.84	0.69	1.21	1.25
Feed per pig, mean, lb.	3.87	3.31	4.82	4.28
Feed per pound gain, mean, lb.	4.6	4.8	4.0	3.4
Physical and Chemical Composition of Carcasses				
Thyroid size, gm.[a]	8.3*	15.2*	4.8**	12.8**
Liver size, lb.[a]	1.7**	2.5**	2.1	2.7
Ratio lean to fat (mechanically separated) in ham	2.768*	3.483*	2.901	3.062
Thickness of back fat, mean, mm.	19.2	16.2	20.2	22.0
Ham, total edible portion, Composition, percent				
Water	59.0**	64.8**	59.3**	63.2**
Fat	24.1**	18.2**	24.0**	20.4**
Protein	16.3	16.3	15.9	15.5
Body temperature, F.	102.2	101.8	104.0	103.0

* Difference between treated and controls significant at the 5 percent level.
** Difference between treated and controls significant at the 1 percent level.
[a] Adjusted to a body weight of 100 lb.

At the low temperature feed efficiency was significantly greater in the pigs given thiouracil than in the controls when the data in trials 1, 3, 4 and 5 were pooled. Only trial 2 gave opposite results. At the higher temperature, however, the difference between thiouracil fed pigs and controls was not significant.

The pigs treated at the lower temperature had significantly greater daily gains. This was in spite of attempts to limit rate of gain by

limiting the feed of the treated group. Again the results in trial 2 did not conform to the usual pattern in the other trials. At the higher temperature the treated pigs had a significantly lower daily gain. The results of trial 2 again went in the other direction.

Livers were larger in all the treated pigs than in controls. There was a greater difference in liver size between treated and control pigs in the "cold" group than in the "hot" group. The livers of control pigs at the high temperature were heavier than those of control pigs at the low temperature. In the treated pigs, those treated at the low temperatures had livers larger than those of pigs treated at the higher temperatures. In trial 2 liver sizes were significantly larger in the treated pigs ($P<.01$).

Thyroid glands were larger in all treated pigs than in control pigs. Thyroids were also larger in control pigs kept at the high temperature, than in control pigs kept at the low temperature. Thyroids of pigs fed thiouracil were larger when kept at the low temperatures.

Backfat was significantly thicker in controls than in treated pigs at the low temperature. Thickness of backfat was essentially the same between pigs treated with thiouracil and controls at the higher temperature.

Results showed that at the low temperature the ratio of lean to fat in the hams was greater in pigs treated with thiouracil than in the controls. This was also true in pigs treated at the higher temperature except in trial 5. There was no significance at the higher temperature. The lean-fat ratio in control pigs was higher at the higher temperature. This was highly significant. The lean-fat ratio in treated pigs was higher in those treated at the low temperature.

In pigs at the lower temperature there was a small but consistent increase in the percentage of protein in the hams. This was highly significant but of small magnitude. There was no significant difference between control and treated pigs at the higher temperature in percentage of protein in the hams. There was a significantly greater percentage of protein in the hams of control pigs at the higher temperature than in those of control pigs at the lower temperature. There was no significant difference between the percentages of protein in the hams of pigs treated with thiouracil at the two different temperatures.

The percentage of water in the hams was greater in the thiouracil treated pigs at both temperatures than in the control pigs. Those treated at the lower temperature had a greater percentage of water in the hams than those treated at the higher temperature. In the control pigs, those

held at the higher temperature had a greater percentage of water in their hams than those held at the lower temperatures.

The percentage of fat in the hams of control pigs was significantly greater than in those of treated pigs at both the high and low temperatures. However, the differences between treated and control pigs were greater at the low temperature than at the high temperature.

Mean body temperatures were slightly lower in the thiouracil treated pigs than in the control pigs.

Discussion

It has been established that treating pigs at young ages and small sizes with thiouracil reduces the rate of gain and the economy of feed consumption. (Willman *et al.*, 1946; Beeson *et al.*, 1947; Vander Noot *et al.*, 1948). Trial 2 bears out this finding. However, even in trial 2, the carcass characteristics reacted to treatment in much the same way as in the other trials.

In feeding pigs individually there was a great deal of wastage of feed. For this reason we do not make a point of feed efficiency. For purposes of this paper we are attempting to show only that the feed efficiency was not lowered by treatment.

It is clear from our results that thiouracil feeding reduced the deposition of fat significantly and increased the percentage of protein in the hams slightly but significantly at the lower temperature. This was not true at the higher temperature. There is evidence of a definite influence of temperature upon the results that can be expected from the feeding of thiouracil. There was also a temperature effect between control pigs treated at the high and low temperatures.

In daily gains there was even more evidence of the influence of temperature upon the results of thiouracil feeding. The same thing was true when thickness of backfat, percentage of water and fat in the hams, sizes of thyroid glands, and size of livers are considered. The effects of thiouracil feeding were more pronounced in each case at the lower temperature.

It appears that if a leaner hog with a higher percentage of protein and a higher ratio of lean to fat is desired without sacrificing rate of gain or feed efficiency, thiouracil may be of some value at low temperatures. It apparently has little, if any, benefit at the higher temperatures. From a practical standpoint, thiouracil feeding during the winter might be expected to improve carcass quality without sacrificing rate

of gain or feed efficiency. Such treatment would not be expected to be beneficial during the summer months.

It may be well to mention here that either the high temperature or the low temperature might bring about a stress reaction involving the adrenal gland.

It has been reported (Dempsey and Astwood, 1943) that the thyroid glands of rats discharge more thyroxin into the blood stream at lower temperatures than at higher temperatures. This is as would be expected. The cutting down of the amount of thyroxin during the period of high secretion appears to be beneficial from the hog raisers standpoint. The further cutting down of the supply of thyroxin in summer when the supply is already low, appears to be detrimental to the welfare of the pig and of the hog farmer. The metabolic rate of the pig is higher during the winter to compensate for the additional heat loss due to the cold weather. This higher metabolic rate may overcompensate for the need for heat. Fattening within itself may partly be an adaptation to cold weather. Both the tendency to fatten and the higher metabolic rate may have a tendency to overdo the adaptation reaction. Thiouracil at the right levels may reduce this overcompensation to a level that is better for the pig and thus for the farmer. The reduction of the tendency to fatten in this experiment may be due to the limitation of feed for the treated animals.

The levels of thiouracil to be fed profitably may vary with the genetics of the pig. Pigs which fatten readily may require more than pigs which are genetically of a leaner type. The interaction of genetics on thiouracil feeding and on hormone treatments of other kinds raises interesting possibilities. It may be that the interaction of genetics and environmental factors will require different treatments for pigs raised in different sections of the country or possibly both different genetic constitution and different feeding methods for different sections. This is suggested by the difference in results reported by different investigators using similar genetic material and similar feeds at different locations.

Thiouracil is thought to produce its effect primarily by action upon the thyroid gland. It may also affect other structures. Since some of the other endocrine glands are concerned with the metabolic rate they may also be affected directly by treatment with thiouracil in addition to being affected indirectly through the thyroid. The effects of this substance upon liver size also poses some unanswered questions.

Summary and Conclusions

The effects of thiouracil treatment of pigs were modified or changed by differences in environmental temperature. At a temperature near 50° F., treatment with thiouracil resulted in decreased backfat thickness and an increased percentage of protein in the hams of pigs treated over controls. There was a greater difference in percentage of water and fat in the hams of pigs treated at around 50° F. and control pigs than in treated pigs and controls at around 90° F. The difference between pigs treated with thiouracil and control pigs in ratio of lean to fat in the hams was greater when the hogs were treated at 50° F. than in hogs treated at 90° F. Livers and thyroids were larger in animals treated at both temperatures than in controls but the difference between the sizes of these organs in treated pigs and in controls was greater at the lower temperature. Rate of gain was increased at the lower temperature by treatment with thiouracil but not at the higher temperature. The difference in economy of feed utilization appears from these data to be greater between the pigs treated at the lower temperatures and controls than between the treated and control pigs at the higher temperature. Thiouracil reduced body temperatures slightly.

Literature Cited

Beeson, W. M., F. N. Andrews, H. L. Witz and T. W. Perry. 1947. The effect of thyroprotein and thiouracil on growth and fattening of swine. JOURNAL OF ANIMAL SCIENCE 6:482.

Dempsey, E. W. and E. B. Astwood. 1943. Determination of the rate of thyroid hormone secretion at various environmental temperatures. Endocr. 32:509.

Vander Noot, G. W., R. P. Reece and W. C. Skelley. 1948. Effects of Thyroprotein and of thiouracil alone and in sequence in the ration of swine. JOURNAL OF ANIMAL SCIENCE 7:84.

Willman, J. P., J. K. Loosli and E. W. Klosterman. 1946. Annual Report Cornell Agr. Exp. Sta. p. 103.

THE COMPARATIVE VALUE OF ANTIBIOTICS AND ARSONIC ACIDS FOR GROWING PIGS [1, 2]

L. E. HANSON, E. G. HILL [3] AND E. F. FERRIN

University of Minnesota

IN prior studies at this Station (Hanson *et al.*, 1955a) chlortetracycline (Aureomycin), oxytetracycline (Terramycin) and procaine penicillin were shown to be effective in increasing live-weight gains of growing pigs. Studies started a year later with p-aminophenylarsonic acid (arsanilic acid) were less conclusive (Hanson *et al.*, 1955b). Experiments with suckling pigs during the spring of 1953 indicated that arsanilic acid was effective in increasing the growth rate of these younger animals (Hanson and Ferrin, 1953).

The present studies were initiated in the summer of 1953 to compare directly the value of a broad-spectrum antibiotic (chlortetracycline) and a narrow-spectrum antibiotic (procaine penicillin) with arsanilic acid, 3-nitro-4-hydroxyphenylarsonic acid [4] and with a combination of each antibiotic and arsanilic acid. A new antibiotic, erythromycin (Erythrocin, Abbott) was also included in the experiment.

Procedure

Eight ration treatments were compared. There were 4 feeding trials with 5 pigs each per treatment. Spring-farrowed pigs were fed in the first two and fall-farrowed pigs in the last two trials. The spring pigs were farrowed on concrete and were used during the last 5 weeks of the suckling period to study the value of chlortetracycline, procaine penicillin or arsanilic acid when added to the creep ration. They were weaned at 8 weeks of age and started in the present experiment immediately.

The fall pigs were also farrowed on concrete but were moved to pasture with their dams when the pigs were one week of age. These pigs were fed chlortetracycline in the creep ration during the 7 weeks of

[1] Paper No. 3389, Scientific Journal Series of the Minn. Agr. Exp. Sta., St. Paul.

[2] This study was supported in part by grants and supplies from Abbott Laboratories, North Chicago, Illinois; Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York and Merck & Co., Inc., Rahway, New Jersey. Acknowledgment is due Dr. S. N. Singh for the statistical evaluation of the data; to Dr. W. J. Aunan for collection of the tissue samples; and to Glen Swartz and associates who fed and cared for the pigs.

[3] The Hormel Institute, Austin, Minn.

[4] 3-nitro-4-hydroxyphenylarsonic acid will be referred to as 3-nitro.

TABLE 1. COMPOSITION OF BASAL MIXTURES FED

Feeding period	Weaning to 125 lb.	From 125 to 200 lb.
Estimated crude protein, percent	14	11
Ingredients	%	%
Yellow corn (ground No. 2)	80.2	88.5
Soybean oil meal (44%)	8.2	2.8
Tankage (dry rendered-60%)	3.6	1.2
Linseed oil meal (36%)	1.8	0.6
Alfalfa meal (dehydrated-17%)	5.0	5.0
Steamed bone meal	0.7	1.4
Salt (trace mineralized) [a]	0.5	0.5
Vitamin supplement [b]	+	+

[a] Guaranteed to contain 0.250 percent Mn; 0.160 percent Fe; 0.033 percent Cu; 0.010 percent Co; 0.007 percent I_2 and 0.005 percent Zn.

[b] Vitamin supplement mixture provided the following calculated additions to each pound of ration: 1 mg. riboflavin, 2 mg. pantothenic acid, 4.5 mg. niacin, 5 mg. choline, 30 mcg. folic acid, 5 mcg. B_{12} and 900 U.S.P. units vitamin D_3. B-vitamins, except B_{12}, provided by a feed supplement Fortafeed 2–49C (Lederle); Vitamin B_{12} provided by Profactor B (Lederle) or by Aurofac (Lederle), see footnote in Table 2; vitamin D_2 was provided by irradiated yeast (Standard Brands Type 9F).

the pasture period. The pigs were weaned at 8 weeks and one trial was started immediately. The second was started when the pigs were approximately 10 weeks old.

In all trials the pigs were sorted on the basis of litter (previous treatment), sex and initial weight and allotted by chance to the various treatments. The pigs were self-fed and watered and were housed in a barn provided with outside paved runways. The basal mixtures fed and the ration treatments are given in tables 1 and 2, respectively.

At the conclusion of the feeding period for trials 3 and 4 (fall farrowed pigs) 7 control pigs and 8 pigs from each of the treatment

TABLE 2. RATION TREATMENTS

Lot No.	Supplement added [a]	Level, mg. per lb. of feed
1	None-Control	....
2	Chlortetracycline	5
3	Procaine penicillin	5
4	Erythromycin	5
5	Arsanilic acid	30
6	3-nitro-4-hydroxyphenylarsonic acid	18.5
7	Chlortetracycline and arsanilic acid	5 & 30, resp.
8	Procaine penicillin and arsanilic acid	5 & 30, resp.

[a] Aurofac (Lederle) was the source of chlortetracycline (and B_{12}) for lots 2 and 7; Pro-Pen "4" (Merck) was the penicillin supplement fed to lots 3 and 8; crystalline erythromycin (Abbott) was fed to lot 4; Pro Gen 20 percent (Abbott) was the source of arsanilic acid for lots 5, 7 and 8; crystalline 3-nitro-4-hydroxyphenylarsonic acid (Abbott) was fed to lot 6.

groups fed an arsonic acid were slaughtered. Samples of liver, kidney, loin muscle and hanging tenderloin muscle were taken from each carcass and quick-frozen for later arsenic determinations.

TABLE 3. A COMPARISON OF ANTIBIOTICS, ARSONIC ACIDS, AND A COMBINATION OF AN ANTIBIOTIC WITH ARSANILIC ACID FOR GROWING PIGS FED IN DRY LOT. SUMMER 1953, WINTER 1953–54. (DATA GIVEN ARE AVERAGES OF 4 TRIALS; 5 PIGS PER LOT; 20 PIGS PER TREATMENT [a])

Lot No.	Ration treatment [b]	Av. daily feed	Av. daily gain	Feed per 100 lb. gain
	mg. per lb.	lb.	lb.	lb.
	Early Growth—Weaning [c] to 125 lb.			
1	None	4.6	1.54	298
2	C, 5	4.7	1.62	289
3	P, 5	4.6	1.60	301
4	E, 5	4.6	1.55	303
5	A.A., 30	4.8	1.53	309
6	3 N, 18.5	4.9	1.61	306
7	C, 5 & A.A., 30	4.8	1.63	296
8	P, 5 & A.A., 30	4.8	1.63	294
	Late Growth—125 to 200 lbs.			
1	None	7.9	1.86	426
2	C, 5	7.7	1.96	395
3	P, 5	7.9	1.92	410
4	E, 5	7.8	1.90	409
5	A.A., 30	7.9	1.90	414
6	3 N, 18.5	7.7	1.91	405
7	C, 5 & A.A., 30	7.8	1.90	410
8	P, 5 & A.A., 30	7.7	1.90	405
	Entire Feeding Period—Weaning to 200 lb.			
1	As given above	5.9	1.66	356
2		6.0	1.76	338
3		5.8	1.72	350
4		5.8	1.69	350
5		6.0	1.68	356
6		6.1	1.73	350
7		6.0	1.74	347
8		6.0	1.74	344

[a] Eighteen pigs finished in lot 3; 2 were removed in the early growth period due to severe parakeratosis. Nineteen pigs finished in lot 4; one was removed because of failure to grow during the early growth period. Gain data are calculated on a pig day basis.

[b] C=chlortetracycline; P=procaine penicillin; E=erythromycin; A.A.=arsanilic acid; 3 N=3-nitro-4-hydroxyphenylarsonic acid.

[c] The first 3 trials were started at weaning; the fourth about 2 weeks after weaning. Average initial weights were 38, 38, 27 and 33 lb. for trials 1, 2, 3 and 4, respectively.

Results and Discussion

Feed Lot Data

The pigs in all lots made excellent gains, as shown in table 3. The average daily gain for all treatments during the early growth period was 1.59 lb. per pig. From 125 to 200 lb. the average was 1.91 lb. per pig.

In 3 of the 4 trials the daily gains of the pigs fed chlortetracycline, procaine penicillin or the combination of either antibiotic with arsanilic acid exceeded the gains of the control pigs. The results obtained with arsanilic acid, 3-nitro or with erythromycin were less consistent. Covariance analysis (Snedecor, 1946) of the growth data, given in table 4, showed that none of the differences between ration treatments were mathematically significant.

TABLE 4. COVARIANCE ANALYSIS OF RATE OF GAIN FROM INITIAL TO FINAL WEIGHTS

Source of variation	Degree of freedom	Sum of squares and products			Errors of estimate		
		x^2	xy	y^2	Sum of squares	Degree of freedom	Mean square
Total	156	7871.975	109.134	6.641			
Between sub-classes	31	3035.758	21.750	1.111			
Between rations	7	3.459	−0.111	0.146			
Between trials	3	2977.211	21.383	0.305			
Ration X trial	21	55.088	0.478	0.660			
Within sub-classes	125	4836.217	87.384	5.530	3.951	124	0.032
Ration + within sub-classes	132	4839.676	87.273	5.676	4.102	131	
For testing significance of adjusted ration means					0.151	7	0.022

In each of the 4 trials the chlortetracycline-fed pigs (lot 2) and the pigs fed a combination of penicillin and arsanilic acid (lot 8) required slightly less feed per unit of gain than the control pigs. The differences were small in most cases and add up to a 5 percent difference only for the pigs fed chlortetracycline.

The response obtained by antibiotic feeding in this experiment is very much less than that reported earlier (Hanson *et al.*, 1955a). A summary of live-weight gains of pigs in this herd fed chlortetracycline or procaine penicillin from 1951 to 1955 is given in table 5.

In the 1951 and '52 experiments the pigs at the start appeared to be in relatively good health. However, there was some scouring in the control lots during the early part of the experiments. The pigs fed

during the summer of 1953 (present experiment) came from an excellent crop in which no difficulty had been experienced during the suckling period. They were, from all outward appearances, easily the best group of pigs fed in this series. The 1953–54 pigs (present experiment) came from a group in which most of the pigs and their dams were severely affected with influenza during the suckling period, and weaning weights (8 weeks) for the entire crop averaged only slightly more than 24 lb. The pigs fed last winter (1954–55) had been weaned at 3 weeks and there was a high incidence of diarrhea in this group prior to weaning

TABLE 5. THE EFFECT OF TWO ANTIBIOTICS ON LIVE WEIGHT GAINS OF PIGS IN THE UNIVERSITY HERD OVER A PERIOD OF 5 YEARS

Treatment		Control	Chlortetracycline 5 mg. per lb. feed	Procaine penicillin 5 mg. per lb. feed
Year [a]	Av. initial wt. of pigs, lb.	Average daily gain from 8–10 weeks to 200 lb.		
1951	33	1.40	1.63	1.54
1952	36	1.45	1.63	1.55
1953 [b, c]	38	1.74	1.79	1.76
1953–54 [c]	30	1.59	1.73	1.67
1954–55	32	1.54	1.65	....

[a] All pigs were fed in dry lot. The pigs fed in 1951, '52 and '53 were spring pigs and the 1953–54 and 1954–55 pigs were fall farrowed.

[b] In 1951 and '52 the basal ration contained approximately 18 percent protein from weaning to 125 lb. and 15 percent protein from 125 to 200 lb. The ration fed in 1953 and later years contained approximately 14 percent protein from weaning to 125 lb. and 11 percent protein thereafter. A B-complex supplement was added to the basal ration in 1953 and thereafter.

[c] These values are combined and given in table 3.

and for about 10 days later. However, they were not scouring when placed in the test pens at 8–10 weeks of age.

It appears from this summary that the lack of response to the antibiotics in 1953 was due to the large improvement in the performance of the control pigs and not to a reduction in the rate of gain of the pigs fed antibiotics. In the later experiments, in which the initial weights and overall quality of the pigs was not as good, there was again a response from antibiotic feeding. There is no evidence in these data to indicate that the organisms which were suppressed by the antibiotics in the 1951, 1952 experiments, have become refractory to the antibiotics fed.

The data obtained in the present experiment support the early find-

ings of Speer *et al.* (1950) with pigs and those of Coates *et al.* (1952) with chicks. Similar observations with pigs and chicks have also been made by others.

There was no evidence of toxicity in any of the pigs fed arsonic acids in the present study.

Arsenic Retention

Fifty gram samples of liver, kidney and loin muscle and the hanging tenderloin muscle from each carcass were obtained at slaughter from control pigs (lot 1) and from pigs fed an arsonic acid in the last two trials of the experiment. Tissue samples were not taken from the pigs fed an antibiotic supplement, but no arsonic acid. The tissue samples were quick-frozen and later analyzed for arsenic (As_2O_3) by the method of Cassil and Wichman (1939). Several of the samples were rechecked by Overby and Crawford (1955) of Abbott Laboratories, by the Evans-Bandemer method. There was good agreement on the samples which were rechecked. A summary of the findings is given in Table 6.

The results of the assays are similar to those reported previously (Hanson *et al.* 1955b). Arsenic retention was related to the level fed and the level retained was approximately twice as great in the liver as in the kidney tissue. Arsenic retention in the muscle was of a very low order. Withdrawal of arsenic from the ration a few days prior to slaughter resulted in a rapid reduction of retained arsenic in the liver and kidneys.

The hanging tenderloin muscle was included in this assay because it can be obtained without cutting the carcass. It was felt that if this muscle could be considered representative of carcass muscle, later studies could be made if desired, without prior processing of the carcass to obtain a sample of loin muscle. The limited data obtained in this experiment indicate that the loin muscle and the hanging tenderloin muscle are similar insofar as arsenic retention is concerned.

Summary

One hundred and sixty purebred pigs were fed in 4 trials of 8 ration treatments with 5 pigs per lot. Chlortetracycline (Aureomycin), procaine penicillin, erythromycin, arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid were compared with each other and with a combination of arsanilic acid and chlortetracycline and with arsanilic acid and procaine penicillin.

In 3 of the 4 trials the daily live weight gains of the pigs fed chlortetracycline, procaine penicillin or the combination of either antibiotic with arsanilic acid exceeded the gains of the control pigs. None of the differences between treatments was significant at the 5 percent level. The pigs fed chlortetracycline had the largest and most consistent superiority over the control group in feed efficiency, but this amounted to only 5 percent.

TABLE 6. SUMMARY OF ARSENIC CONTENT OF TISSUES FROM SWINE FED ARSONIC ACIDS (VALUES ARE MICROGRAMS As_2O_3 PER GRAM OF FRESH TISSUE)

Treatment group	No. pigs	Days[a]	Liver	Kidney	Loin	H.T.[b]
Control-Lot 1	7	0	0.04	0.09	0.02	0.02
Arsanilic acid (60 gm. per ton)–Lot 5						
	2	0	3.00	1.86	0.30	0.34
	2	2	1.91	0.36	0.08	0.05
	2	4	1.60	0.29	0.18	0.17
	2	7	0.94	0.24	0.04	0.00
3-Nitro-4-hydroxyphenylarsonic acid (37 gm. per ton)–Lot 6						
	2	0	1.90	1.12	0.12	0.34
	2	2	0.77	0.64	0.12	0.08
	2	4	0.51	0.44	0.15	0.08
	2	7	0.33	0.36	0.02	0.04
Chlortetracycline (10 gm. per ton) + arsanilic acid (60 gm. per ton)–Lot 7						
	2	0	2.64	1.46	0.23	0.22
	2	2	2.06	0.48	0.04	0.04
	2	4	0.72	0.34	0.12	0.10
	2	7	1.18	0.18	0.12	0.09
Penicillin (10 gm. per ton) + arsanilic acid (60 gm. per ton)–Lot 8						
	2	0	3.08	1.57	0.04	0.08
	2	2	2.27	0.47	0.02	0.01
	2	4	0.86	0.33	0.04	0.11
	2	7	1.17	0.23	0.18	0.00

[a] Days elapsed after withdrawal of arsonic acid from ration prior to slaughter.
[b] Hanging tenderloin muscle.

The lack of a significant response to antibiotics or arsonic acids is attributed to the generally high quality of pigs fed in this experiment.

Arsenic assays of tissues of pigs fed arsonic acids alone or in combination with antibiotics showed that arsenic retention was related to the level of arsenic fed. This confirms the previous findings at this Station. There was no evidence of toxicity in any of the pigs fed arsonic acids.

Literature Cited

Cassil, C. C. and H. J. Wichman. 1939. A rapid volumetric micro method for determining arsenic. J. Ass'n Official. Agric. Chem. 22:436.

Coates, M. E., C. D. Dickinson, G. F. Harrison, S. K. Kon, J. W. G. Porter, S. H. Cummins and W. F. J. Cuthbertson. 1952. A mode of action of antibiotics in chick nutrition. J. Sci. Food Agric. 3:43.

Hanson, L. E., E. F. Ferrin, P. A. Anderson and W. J. Aunan. 1955a. Growth and carcass characteristics of pigs fed antibiotics for part or all of the growing-fattening period. JOURNAL OF ANIMAL SCIENCE 14:30.

Hanson, L. E., L. E. Carpenter, W. J. Aunan and E. F. Ferrin. 1955b. The use of arsanilic acid in the production of market pigs. JOURNAL OF ANIMAL SCIENCE 14:513.

Hanson, L. E. and E. F. Ferrin. 1953. Aureomycin, procaine penicillin or arsanilic acid improves a pig starter for suckling pigs. Department of Animal Husbandry. 31st Swine Feeders Day Report, September, p. 18.

Overby, L. R. and L. E. M. Crawford. 1955. Personal Communication.

Snedecor, G. W. 1946. Statistical Methods, 4th Edition, The Iowa State College Press, Ames, Iowa.

Speer, V. C., R. L. Vohs, D. V. Catron, H. M. Maddock and C. C. Culbertson. 1950. Effect of aureomycin and animal protein factor on healthy pigs. Arch. Biochem. 29:452.

THE INFLUENCE OF TRYPTOPHAN, METHIONINE AND LYSINE SUPPLEMENTATION OF A CORN-SOYBEAN OIL MEAL DIET ON NITROGEN BALANCE OF GROWING SWINE [1]

R. J. MEADE [2, 3]

Nebraska Agricultural Experiment Station [4]

MANY investigations have been conducted to determine the amino acid content of a wide variety of feedstuffs, many of which are commonly used in typical swine diets (Block and Mitchell, 1946; Baumgarten *et al.*, 1946; Williams *et al.*, 1955). The lysine requirement for growing pigs has been reported by Mertz *et al.* (1949), Brinegar *et al.* (1950) and Shelton *et al.* (1951a). A strict tryptophan deficiency was first produced in growing pigs by Beeson *et al.* (1949), and the requirement set forth by the National Research Council (1953) is based on the work of Shelton *et al.* (1951b, 1951c). Bell *et al.* (1950) and Curtin *et al.* (1952) have reported the methionine requirement for growing swine. A comparison of these reported essential amino acid requirements of growing pigs with calculated amino acid content of many practical diets, particularly those containing lower levels of protein, reveals that many such diets may be inadequate in these essential amino acids.

Several workers (Bloss *et al.*, 1953; Terrill *et al.*, 1954; Henson *et al.*, 1955) have recently demonstrated that the addition of small amounts of dl-tryptophan to corn-meat by-product type of diets improved them for growing-fattening pigs. Becker *et al.* (1955) have demonstrated that a corn-fish meal type of diet was significantly improved by the addition of dl-tryptophan. Although typical corn-soybean oil meal diets containing 14 to 16 percent of crude protein

[1] Published with the approval of the Director as Paper No. 724, Journal Series. A part of the thesis submitted by the author to the graduate college, University of Illinois, Urbana, in partial fulfillment of the requirements for the Doctor of Philosophy Degree.

[2] Acknowledgment is made of partial support of this investigation through contributions of funds or supplies by Dow Chemical Company, Midland, Michigan; E. I. duPont deNemours and Co., Inc., Wilmington, Delaware; Merck and Co., Inc., Rahway, New Jersey; Chas. Pfizer and Company, Inc., Brooklyn, New York; and Swift and Company, Chicago, Illinois.

[3] Dr. Ruth M. Leverton and associates, Human Nutrition Laboratory, University of Nebraska, generously made the amino acid analyses. Dr. C. W. Ackerson and associates, Department of Biochemistry and Nutrition, University of Nebraska, assisted with the nitrogen determinations. Messrs. Fred Krieger and Ward Lingo helped with the feeding and caring for experimental animals.

[4] Lincoln.

appear to be slightly inadequate in tryptophan, methionine, and lysine when their amino acid content is compared to the reported requirements for these amino acids, only in the work of Dyer *et al.* (1949), was methionine supplementation found to significantly improve such a diet. Almquist (1942) previously reported high soybean oil meal diets to be inadequate in methionine for growing chicks. Forbes (1954) reported a significant improvement in nitrogen balance of growing albino male rats due to the addition of methionine to 12 percent crude protein semi-purified type of diets in which soybean oil meal was the source of protein.

Becker *et al.* (1954) recently reported that diets containing 0.13, 0.23, and 0.63 percent of tryptophan, methionine and lysine, respectively, were adequate to promote acceptable growth of 40 to 100 lb. pigs. Williams *et al.* (1954) on the basis of carcass assays suggested requirements of 0.10, 0.23, and 1.10 percent of tryptophan, methionine and lysine, respectively, for pigs. Only in the case of the lysine requirement, suggested by the latter group is the amino acid content of a 14 to 16 percent crude protein diet notably below the possible requirements just cited. Thus, the failure to improve a corn-soybean oil meal type of diet with methionine supplementation reported by Curtin *et al.* (1952), or to significantly improve such a ration with methionine and lysine supplementation as found by Catron *et al.* (1953) is not unexpected.

This investigation was conducted to determine the influence of dl-tryptophan, dl-methionine and l-lysine supplementation of an approximately 16 percent crude protein corn-soybean oil meal diet, adequate in non-protein dietary factors, upon nitrogen utilization by growing pigs. It was considered that the nitrogen balance technique provided an excellent method by which to study utilization of dietary protein, as affected by the addition of supplemental amounts of the amino acids under investigation.

Experimental Procedures

Twenty-four purebred Hampshire and Hampshire x Duroc weanling barrows weighing approximately 32 kg. each, at the time of the first collection of excreta, were used in this experiment.

The group of 24 barrows was subdivided into three subgroups of 8 barrows each, and each of these subgroups was further subdivided into smaller groups of 4 pigs each. One of the main subgroups was assigned to each of the amino acids under investigation. One unit of 4 pigs

assigned to a given amino acid was on fecal and urine collection while the other 4 pigs were on individual feed during the preliminary period.

Animals were fed twice daily and the feed intake was maintained at a constant level of about 4.25 percent of body weight throughout the final 4 days of the preliminary period and the entire collection period. Nitrogen balance data were obtained using 8 to 10 day preliminary periods followed by 6-day collection periods. All collections were made using adjustable cylindrical swine metabolism cages patterned after those designed by Bell (1948). Nitrogen determinations were made according to the Kjeldahl-Gunning-Arnold method, using a copper catalyst during the digestion process.

The composition of the basal diet is shown in table 1. This diet

TABLE 1. COMPOSITION OF BASAL DIET—EXPERIMENT II

Ingredients	Percent
Ground yellow corn	80.05
Solvent soybean oil meal	15.70
Dicalcium phosphate	3.50
Iodized salt	0.50
Vitamin-antibiotic-trace element premix [a]	0.25

[a] Furnished 2.2 mg. riboflavin, 8.8 mg. calcium pantothenate, 22 mg. niacin, 220 mg. choline chloride, 11 mcg. vitamin B_{12}, 4400 I.U. vitamin A, 220 I.U. vitamin D_3, 22 mg. terramycin, 33 mg. iron, 17.6 mg. manganese, 3.3 mg. zinc, 3.3 mg. copper and 1.1 mg. cobalt per kilogram of diet.

contained 15.9 percent of crude protein based on the nitrogen content of the basic ingredients (corn contained 17.2 mg. of nitrogen per gm. and soybean oil meal contained 73.1 mg. of nitrogen per gm., air dry basis). The diet contained the following percentages of the amino acids indicated as determined by microbiological assays of the basic ingredients: tryptophan, 0.132; methionine, 0.27; lysine, 0.69; histidine, 0.39; isoleucine, 0.70; leucine, 1.65; phenylalanine, 0.67; threonine, 0.59; and valine, 0.78.

This investigation was divided into three parts, each with a different test amino acid, with the same basal diet being used throughout. Part A was devoted to tryptophan and levels of 0, 0.03, 0.06 and 0.09 percent of dl-tryptophan were added to supply final levels of 0.132, 0.147, 0.162, and 0.177 percent of avalable tryptophan, if the d-isomer is totally unavailable to the pig. Uniform amino acid additions were made to provide final levels of 0.37 and 0.76 percent of methionine and lysine, respectively. Seven collection periods were completed; however, the

data for one pig were lost during the second collection period and the data for other pigs on collection during this period have therefore been omitted. As a consequence, the results of this part of the investigation are based on the data obtained during six collection periods.

Supplementation of 0, 0.025, 0.05 and 0.10 percent of dl-methionine was made in Part B to provide final methionine levels of 0.27, 0.295, 0.32 and 0.37 percent of the diet. Uniform additions of l-lysine and dl-tryptophan were made to provide final levels of 0.76 and 0.152 percent, respectively, of these amino acids in each of the test diets. Seven collection periods were completed on each of the test levels of methionine.

The test amino acid in Part C was lysine. L-lysine was added at levels of 0, 0.038, 0.075 and 0.15 percent of the diet to provide final levels of 0.69, 0.728, 0.765 and 0.85 percent of lysine. Uniform amino acid additions were made to provide final levels of 0.152 and 0.37 percent of tryptophan and methionine, respectively, in each of the test diets. As was the case in Part A, the data of one pig were lost during collection period 2 with the result that data from only six collection periods are used in reporting the findings of this phase of the study.

Although the levels of amino acids other than the test amino acid were thought to be adequate, based on results obtained with pigs individually fed 14 percent crude protein diets ad libitum (Meade, 1954), it was recognized that the level of lysine, in particular, was considerably lower than the reported requirement. Methionine might have been slightly inadequate if the reported requirements are accepted. Constant levels of the two amino acids not under investigation were added to each diet in an attempt to eliminate the likelihood of a deficiency of other than the test amino acid without providing gross excesses of those particular amino acids.

The corn used in this experiment contained 10.8 percent crude protein, and contained smaller percentages of the essential amino acids than did an 8.0 percent crude protein corn which was analyzed at the same time. Eggert *et al.* (1953) reported that the proteins of normal and high protein corn were not of equal value in promoting nitrogen balance of growing pigs. However, differences in nitrogen balance of pigs due to protein content of the corn were largely eliminated by tryptophan and lysine supplementation of the high protein corn.

All data have been summarized to present animal weights as mean weight expressed in kilograms for the time that the individual animals were maintained on collection. These mean weights of the individual

animals have been reduced to $W_{Kg.}^{0.734}$ to eliminate insofar as possible the influence of differences in body weight, W, between different pigs and different periods (Brody and Procter, 1932). Data are presented showing the daily nitrogen metabolism of the pigs used in the various studies and the daily nitrogen metabolism per $W_{Kg.}^{0.734}$. All conclusions are based on daily nitrogen retention per $W_{Kg.}^{0.734}$. Data have been treated statistically using analysis of variance and covariance analysis as set forth by Snedecor (1946).

Results and Discussion

The average nitrogen metabolism data presented in table 2 indicate no large differences in nitrogen retention of growing pigs due to the addition of any of the supplemental levels of any one of the test amino acids. Likewise, no one of the three test amino acids appears to have increased nitrogen retention more than the other test amino acid when the diets were fed to pigs with $W_{Kg.}^{0.734}$ values of 11.619 to 22.158.

The adjusted mean nitrogen retention values are not shown as covariance analysis and application of the regression coefficient did not significantly improve the mean nitrogen retention values. There was so little difference in the mean $W_{Kg.}^{0.734}$ values for the 4 treatments pertinent to a given amino acid that the adjusted mean nitrogen retention values differed little, if at all, from the mean values shown in table 2.

Statistical treatment of the data for the various parts of the study (Parts A, B, and C) by analysis of covariance indicated that within each of the given parts there was no significant improvement in grams of nitrogen retained per $W_{Kg.}^{0.734}$ due to the addition of supplementary amounts of each of the test amino acids. There was a rather consistent decrease in nitrogen retention when supplemental dl-tryptophan was added in increasing amounts (part A). Although this may have been a very real trend, the differences were not of sufficient magnitude to render the largest difference statistically significant. No such trend was apparent when supplemental dl-methionine was added, but a trend toward decreased nitrogen retention was evident when progressively larger amounts of l-lysine were added.

Levels of 0.132, 0.27, and 0.69 percent of tryptophan, methionine and lysine, respectively, present in the basal diet prior to supplementation with the crystalline amino acids appear to have been adequate for growing pigs since nitrogen retention was not improved when crystalline amino acids were added. The indicated amounts of these amino

TABLE 2. AVERAGE NITROGEN METABOLISM DATA FOR PIGS FED CORN-SOYBEAN OIL DIETS SUPPLEMENTED WITH DL-TRYPTOPHAN, DL-METHIONINE, OR L-LYSINE

Amino acid	Final percent in diet	Mean body weight	Average daily increase	Air dry feed consumed daily	Nitrogen metabolism per day				Nitrogen metabolism per day per $W^{0.734}_{kg.}$		
					Intake	Feces	Urine	Balance	Absorbed	Urine	Balance
		kg.	kg.	gm.	gm.	gm.	gm.	gm.	gm.[a]	gm.	gm.
Tryptophan	0.132	49.47	0.772	2104	53.475	11.668	21.864	19.444	2.374	1.222	1.152
	0.147	48.94	0.762	2015	51.318	9.903	21.959	19.456	2.368	1.222	1.146
	0.162	47.97	0.795	2015	51.431	9.618	24.288	17.525	2.435	1.380	1.055
	0.177	49.18	0.740	2076	53.083	10.942	24.683	17.458	2.398	1.368	1.030
Methionine	0.27	43.92	0.749	1861	47.142	10.135	19.401	17.606	2.282	1.163	1.119
	0.295	44.54	0.750	1897	48.138	10.611	20.052	17.476	2.282	1.182	1.100
	0.32	44.36	0.751	1870	47.506	10.318	20.592	16.595	2.280	1.227	1.052
	0.37	44.33	0.748	1877	47.811	10.759	19.704	17.347	2.260	1.161	1.099
Lysine	0.69	45.40	0.738	1923	48.701	9.490	19.693	19.518	2.358	1.173	1.186
	0.728	46.14	0.937	1942	49.342	9.392	21.351	18.599	2.366	1.245	1.121
	0.765	45.21	0.811	1919	48.915	9.789	22.306	16.820	2.368	1.323	1.045
	0.84	45.10	0.805	1915	49.073	10.090	22.152	16.831	2.356	1.298	1.058

[a] Apparently absorbed nitrogen.

acids are but slightly in excess of the amounts indicated by Becker *et al.* (1954) to be adequate for acceptable rate of gain of growing pigs and are also only slightly in excess of amounts of these amino acids contained in 14 percent crude protein diets which supported excellent growth when fed to weanling pigs at this station, (Meade, 1954). Williams *et al.* (1954) have recently estimated that the pig requires less tryptophan and methionine than was present in the basal diet however, their value of the lysine requirement is nearly 160 percent of the amount of lysine contained in the basal diet used in this study.

Although the corn used in the basal diet contained 10.8 percent of crude protein, and contained smaller amounts of tryptophan, methionine and lysine per unit of protein than an 8.0 percent crude protein corn, it is apparent that this relatively simple diet formulated from a medium high protein corn and a high quality solvent soybean oil meal was adequate for satisfactory amino acid nutrition of growing pigs. The diet was formulated to be adequate in non-protein dietary factors.

When the nitrogen metabolism data for the individual pigs were considered, there was some evidence that the 15.9 percent crude protein diet used contained nitrogen in excess of the needs of the larger pigs. As would have been expected, the larger pigs which consumed more total protein per $W_{Kg.}^{0.734}$ apparently absorbed more nitrogen per $W_{Kg.}^{0.734}$; however, these larger pigs also excreted much larger amounts of urinary nitrogen. There was a definite trend toward less efficient utilization of nitrogen for gain by the heavier weight pigs as evidenced by the fact that many of the pigs with $W_{Kg.}^{0.734}$ values of 21 to 22 excreted well over twice as much urinary nitrogen per $W_{Kg.}^{0.734}$ as did pigs with the smaller weight values of 12 to 13.

Summary and Conclusions

The supplementation of a 15.9 percent crude protein diet formulated from a 10.8 percent protein corn and a high quality soybean oil meal with either dl-tryptophan, dl-methionine or l-lysine failed to improve nitrogen retention of growing pigs when the supplemented diets were fed at approximately 4.25 percent of body weight.

Levels of 0.132, 0.27 and 0.69 percent, respectively, of tryptophan, methionine, and lysine in a 15.9 percent crude protein basal diet were adequate to promote acceptable nitrogen retention by growing pigs.

The 15.9 percent crude protein diet used in this series of investigations appeared to contain protein in excess of the needs of pigs weigh-

ing over 40 kg., as evidenced by the marked increase in urinary nitrogen excretion of pigs weighing in excess of 40 kg.

Literature Cited

Almquist, H. J., E. Mecchi, F. H. Kratzer and C. R. Grau. 1942. Soybean oil meal as a source of amino acids for the chick. J. Nutrition 24:385.

Baumgarten, W., A. N. Mather and L. Stone. 1946. Essential amino acid composition of feed materials. Cereal Chem. 23:135.

Becker, D. E., J. W. Lassiter, S. W. Terrill and H. W. Norton. 1954. Levels of protein in practical rations for the pig. JOURNAL OF ANIMAL SCIENCE 13:611.

Becker, D. E., S. W. Terrill and R. A. Notzold. 1955. Supplementary protein and the response of the pig to antibiotics. JOURNAL OF ANIMAL SCIENCE 14:492.

Beeson, W. M., E. T. Mertz and D. C. Shelton. 1949. Effect of tryptophan deficiency on the pig. JOURNAL OF ANIMAL SCIENCE 8:532.

Bell, J. M. 1948. An adjustable cylindrical cage for use in metabolism studies with young swine. Jour. Nutr. 35:365.

Bell, J. M., H. H. Williams, J. K. Loosli and L. A. Maynard. 1950. The effect of methionine supplementation of a soybean oil meal purified ration for young pigs. Jour. Nutr. 40:551.

Block, R. J., and H. H. Mitchell. 1946. The correlation of the amino acid composition of proteins with their nutritive value. Nutr. Abstr. and Rev. 16:249.

Bloss, R. E., R. W. Luecke, J. A. Hoefer, F. Thorp., Jr., and W. N. McMillen. 1953. Supplementation of a corn-meat and bone scraps ration for weanling pigs. JOURNAL OF ANIMAL SCIENCE 12:102.

Brinegar, M. J., H. H. Williams, F. H. Ferris, J. K. Loosli and L. A. Maynard. 1950a. The lysine requirement for the growth of swine. J. Nutr. 42:129.

Brody, S., and R. C. Procter. 1932. Growth and development with special reference to domestic animals. XXIII. Relation between basal metabolism and mature body weight in different species of mammals and birds. Missouri Agr. Sta. Bull. 166.

Catron, D. V., D. C. Acker, R. C. Ashton, H. M. Maddock and V. C. Speer. 1953. Lysine and methionine supplementation of corn-soybean oil meal rations for pigs in drylot. JOURNAL OF ANIMAL SCIENCE 12:910.

Curtin, L. V., J. K. Loosli, J. P. Willman and H. H. Williams. 1952. Methionine as a supplement to soybean oil meal for weanling pigs. JOURNAL OF ANIMAL SCIENCE 11:459.

Dyer, I. A., J. L. Krider and W. E. Carroll. 1949. Known and unidentified factors supplement a corn-soybean meal ration for weanling pigs. JOURNAL OF ANIMAL SCIENCE 8:541.

Eggert, R. G., M. J. Brinegar and C. R. Anderson. 1953. The quality of protein of normal and high protein corn for growing swine. JOURNAL OF ANIMAL SCIENCE 12:282.

Forbes, R. M. 1954. Studies on the influence of antibiotics and methionine on nitrogen utilization and basal metabolism of the growing male albino rat. Jour. Nutr. 53:275.

Henson, J. N., W. M. Beeson and T. W. Perry. 1954. Vitamin, amino acid, and antibiotic supplementation of corn-meat by-product rations for swine. JOURNAL OF ANIMAL SCIENCE 13:885.

Meade, R. J. 1954. Unpublished data.

Mertz, E. T., D. C. Shelton and W. M. Beeson. 1949. The amino acid requirements of swine, Lysine. JOURNAL OF ANIMAL SCIENCE 8:524.

National Research Council. 1953. Nutrient requirements for domestic animals II. Nutrient requirements for swine. National Academy of Science. National Research Council. Publication 295.

Shelton, D. C., W. M. Beeson and E. T. Mertz. 1951a. Quantitative l-lysine requirement of the weanling pig. Arch. Biochem. 30:1.

Shelton, D. C., W. M. Beeson and E. T. Mertz. 1951b. Quantitative dl-tryptophan requirement of the weanling pig. JOURNAL OF ANIMAL SCIENCE 10:73.

Shelton, D. C., W. M. Beeson and E. T. Mertz. 1951c. The effect of methionine and cystine on the growth of weanling pigs. JOURNAL OF ANIMAL SCIENCE 10:57.

Snedecor, G. W. 1946. Statistical methods applied to experiments in agriculture and biology, 4th edition. Iowa State College Press, Ames, Iowa.

Terrill, S. W., D. E. Becker, H. W. Norton, W. K. Warden and C. R. Adams. 1954. Some plant and animal sources of crude protein for weanling pigs fed in drylot. JOURNAL OF ANIMAL SCIENCE 13:622.

Williams, H. H., L. V. Curtin, J. Abraham, J. K. Loosli and L. A. Maynard. 1954. Estimation of growth requirements for amino acids by assay of the carcass. J. Biol. Chem. 208:277.

Williams, H. H. 1955. "Essential" amino acid content of animal feeds. Cornell University Agr. Exp. Sta. Memoir 337.

THE INFLUENCE OF PROTEIN CONTENT OF THE DIET AND OF CHLORTETRACYCLINE AND/OR VITAMIN B_{12} SUPPLEMENTATION UPON PERFORMANCE OF GROWING-FATTENING PIGS [1, 2]

R. J. MEADE [3]

Nebraska Agricultural Experiment Station

IN an early report on the use of APF (Animal Protein Factor) supplements in swine rations Cunha *et al.* (1950) suggested that the protein requirements of swine might need to be re-evaluated using adequate amounts of vitamin B_{12}, plus other factors present in Lederles' APF supplement. Jukes *et al.* (1950) showed that chlortetracycline (Aureomycin) was largely responsible for the increased rate of gain of growing swine fed this APF supplement.

It has since been reported by Catron and coworkers (1952) that corn-soybean oil meal type diets adequate in non-protein dietary factors and containing a 14–11–8 percent protein combination were equal to a 16–13–10 percent combination for pigs from weaning to 75, 75 to 150 and 150 to 200 lb. when chlortetracycline was added to the lower level protein combination. These workers and Burnside *et al.* (1954) suggested that antibiotic apparently effected a protein-sparing action with respect to the pigs' protein needs. Robison (1952), Bowland and McElroy (1952) and Botkin *et al.* (1951) have reported experiments in which lower protein diets supplemented with an antibiotic were equal or superior to higher protein diets without an antibiotic. Hoefer and coworkers (1952) reported 15 and 18 percent crude protein diets containing high levels of B-vitamins with and without oxytetracycline (Terramycin) supplementation to be of equal value for weanling pigs, although highly significant differences in rate of gain resulted from oxytetracycline supplementation at each level of protein. Jensen *et al.* (1955) reported that for an antibiotic to exert a "Protein-sparing"

[1] Published with the approval of the Director as Paper No. 725, Journal Series.

[2] This work partially supported by grants-in-aid or contributions of investigational materials by Lederle Laboratories Division, American Cynamid Company, Pearl River, New York; Merck & Company, Inc., Rahway, New Jersey; and Swift & Company, Chicago, Illinois.

[3] Acknowledgment is made to Mr. Alvah Markussen, Foreman, Swine Research Center, and his associates for their assistance.

effect pigs would have to show a greater response to antibiotic feeding at lower than at higher protein levels.

Becker *et al.* (1954a, 1954b), Hanson *et al.* (1955), Lassiter *et al.* (1955) and Geurin *et al.* (1951) have demonstrated that swine rations adequate in non-protein dietary factors and containing less protein than recommended by the National Research Council (1953) will promote satisfactory rate of gain in growing pigs.

The two experiments reported here were conducted to obtain further information on the optimum protein content of rations fed to growing-

TABLE 1. COMPOSITION OF DIETS, EXPERIMENT 1

Ingredient	Amounts (lb.)				
Ground yellow corn	72.20	64.70	57.20	49.70	42.20
Corn starch	2.45	11.63	20.81	29.99	39.17
Solvent soybean oil meal	16.00	14.20	12.40	10.60	8.80
Meat scraps	8.00	7.10	6.20	5.30	4.40
Crude corn oil		0.35	0.70	1.05	1.40
Ruffex		0.32	0.64	0.96	1.28
Mono-calcium phosphate		0.30	0.60	0.90	1.20
Calcium carbonate	0.50	0.55	0.60	0.65	0.70
Viadex [1]	0.30	0.30	0.30	0.30	0.30
Salt	0.50	0.50	0.50	0.50	0.50
Trace element mixture [2]	0.05	0.05	0.05	0.05	0.05
B-vitamin supplement [3]	+	+	+	+	+
Crude protein, percent	18.10	16.13	14.15	12.17	10.18
Calculated calcium, %	0.89	0.89	0.88	0.89	0.89
Calculated phosphorus, %	0.60	0.59	0.59	0.59	0.59

[1] Contained 4000 I.U. vitamin A and 750 I.U. vitamin D per gram. Generously supplied by Nopco Chemical Company, Harrison, New Jersey, courtesy Dr. M. Hochberg.
[2] Furnished 15 mg. iron, 10 mg. manganese, 1.0 mg. copper, 1.0 mg. zinc and 0.5 mg. cobalt per pound of mixed ration.
[3] Furnished 1.5 mg. riboflavin, 8 mg. calcium pantothenate, 15 mg. niacin and 500 mg. choline chloride per pound of mixed ration.

fattening pigs in drylot, and to determine whether chlortetracycline and/or vitamin B_{12} would exert any influence upon the performance of pigs fed the diets containing the lower levels of protein.

Experimental Procedures

Experiment 1

Sixty weanling purebred Duroc pigs weighing approximately 38 lb. were randomly assigned to 12 groups of five pigs each. A group of five pigs was then assigned at random to each of the 12 experimental treatments employed. The pigs had been creep fed adequate rations during

the preweaning period and only pigs believed to be thrifty were used.

Rations which supplied crude protein combinations of approximately 18–16–14, 16–14–12, and 14–12–10 percent of protein were fed to four lots of five pigs each. The protein level of the rations was reduced by increments of approximately 2 percent when the average pig weight within a lot was approximately 75 lb. and again when the average pig weight was approximately 125 lb. Each test protein level combination was fed with 0, 2, 4, and 8 mg. of supplemental chlortetracycline per pound of diet, making the above total of four lots of pigs on each protein level combination. The test was of 96 days duration.

TABLE 2. COMPOSITION OF DIETS, EXPERIMENT 2

Ingredient	Amounts (lb.)				
Ground yellow corn	75.85	79.85	84.15	88.75	93.05
Solvent soybean oil meal	15.00	12.00	8.80	5.40	2.20
Meat scraps	7.50	6.00	4.40	2.70	1.10
Steamed bonemeal	1.00	1.50	2.00	2.50	3.00
Iodized salt	0.50	0.50	0.50	0.50	0.50
Vitamin-trace element mixture [a]	0.15	0.15	0.15	0.15	0.15
Crude protein percent	17.51	15.44	13.38	11.06	9.35
Calculated calcium, %	0.75	0.77	0.79	0.80	0.81
Calculated phosphorus, %	0.63	0.63	0.61	0.64	0.64

[a] Furnished 1000 I.U. vitamin A, 90 I.U. vitamin D, 2.0 mg. riboflavin, 4.0 mg. calcium pantothenate, 9 mg. niacin, 100 mg. choline chloride, 15 mg. iron, 10 mg. manganese, 1.0 mg. copper, 1.0 mg. zinc and 0.5 mg. cobalt per pound of mixed ration.

The composition of the rations containing the various levels of protein is shown in table 1. An approximate proportion of 9 parts ground yellow corn, 2 parts solvent soybean oil meal, and 1 part of meat scraps was maintained regardless of protein content of the ration. Corn starch, crude corn oil and ruffex were added as the level of protein in the rations was reduced in an attempt to equalize the various rations for energy and crude fiber. The objective of this procedure was to keep the amino acid composition of the various rations in the same relative proportion regardless of level of protein in the diet. Almquist (1952) reported that the relative proportion of the individual amino acids was a more important attribute than level of protein in the diet of chicks.

Experiment 2

Sixty purebred Hampshire and purebred Duroc weanling pigs averaging approximately 53 lb. were randomly allotted to 12 lots of five pigs each. A group of five pigs was then assigned at random to each of the experimental treatments used. These pigs had been fed nutritionally adequate creep rations during the preweaning period and were an exceptionally thrifty group when placed on experiment. The pigs were maintained on this study for a period of 55 days.

Protein level combinations similar to those outlined for Experiment 1 were used in this study. One minor exception was made in that the initial protein level change was not made until the average pig weight within a lot was approximately 80 lb. In this experiment rations of each protein level combination were fed unsupplemented, or supplemented with either 5 mg. chlortetracycline, 5 mcg. vitamin B_{12}, or a combination of the two, per pound of mixed ration. Thus, a total of four groups of pigs was fed on each protein level combination.

The composition of the experimental rations is shown in table 2. In this study ground corn was added to dilute the ration when lowering the level of protein, and the solvent soybean oil meal and meat scraps were maintained at a 2:1 ratio in all rations. This procedure caused the relative proportion of the essential amino acids to be altered when the protein content of the rations was changed. Differences in protein content of the rations of similar protein level combinations used in the two experiments are the result of a protein content of only eight percent in the corn used in Experiment 2. The corn used in Experiment 1 contained nine percent of crude protein.

Results

Experiment 1

Average performance data for the pigs are shown in table 3. The adjusted mean final weights as determined by application of the regression coefficient obtained through covariance analysis (Snedecor, 1946) are also shown.

When the data were analyzed by covariance, adjusting the final weights on the basis of initial weight, there were no significant differences in adjusted average final weights due to protein level combination. Likewise, there was no significant difference due to antibiotic supplementation, nor was there a significant protein x antibiotic interaction.

Experiment 2

Average performance data for pigs fed the rations providing the different protein level combinations supplemented with chlortetracycline and/or vitamin B_{12} are shown in table 4.

TABLE 3. THE INFLUENCE OF CHLORTETRACYCLINE AND PROTEIN CONTENT OF DIET ON THE PERFORMANCE OF GROWING-FATTENING PIGS

Level of antibiotic, mg. per lb. of ration Item	0	2	4	8	By protein level combination
18.1–16.1–14.2—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	38.2	39.6	35.0	37.8	37.6
Adjusted av. final wt., lb.[a]	178.8	185.5	199.2	202.1	191.5
Average daily gain, lb.[b]	1.49	1.59	1.64	1.72	1.61
Feed per lb. gain, lb.	3.18	3.53	3.23	3.34	3.32
16.1–14.2–12.2—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	39.0	37.4	39.4	37.8	38.4
Adjusted av. final wt., lb.[a]	190.4	198.2	197.2	199.5[c]	196.3
Average daily gain, lb.[b]	1.63	1.68	1.70	1.67	1.67
Feed per lb. gain, lb.	3.33	3.35	3.32	3.27	3.32
14.2–12.2–10.2—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	38.8	36.8	35.2	37.2	37.0
Adjusted av. final wt., lb.[a]	183.4[c]	197.8	193.0[c]	191.5	191.6
Average daily gain, lb.[b]	1.52	1.66	1.56	1.62	1.59
Feed per lb. gain, lb.	3.25	3.24	3.13	3.26	3.23
By level of antibiotic					
Number of pigs	15	15	15	15	
Average initial wt., lb.	38.7	37.9	36.5	37.6	
Adjusted av. final wt., lb.[a]	184.2	194.9	196.5	197.7	
Average daily gain, lb.[b]	1.55	1.65	1.64	1.64	
Feed per lb. gain, lb.	3.25	3.37	3.29	3.24	

[a] Average final weight plus correction factor obtained by multiplying deviation from the mean (37.68) by the regression coefficient (2.76). Snedecor (1946).

[b] Unadjusted average daily gains.

[c] A calculated final weight included for one pig removed from test for causes not due to experimental treatments.

Analysis of the data by covariance indicated that there were no significant differences in adjusted final weights of the pigs due to antibiotic and/or vitamin B_{12} supplementation. Differences in final pig weights due to level of protein, although they tend to favor the higher protein levels, were also not significant. The failure to obtain a con-

TABLE 4. THE INFLUENCE OF CHLORTETRACYCLINE AND/OR VITAMIN B_{12} AND PROTEIN CONTENT OF DIET ON THE PERFORMANCE OF GROWING-FATTENING PIGS

Item	Basal	5 mg. antibiotic per lb.	5 mcg. vitamin B_{12}/lb.	5 mg. antibiotic 5 mcg. vitamin B_{12}/lb.	By protein level combination
17.5–15.4–13.4—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	51.6	55.0	55.8	56.2	54.6
Adjusted av. final wt., lb.[a]	148.6[c]	156.6	147.0	147.9	148.6
Average daily gain, lb.[b]	1.69	1.89	1.73	1.76	1.75
Feed per lb. gain, lb.	2.69	2.96	2.96	2.96	2.89
15.4–13.4–11.1—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	54.8	53.0	54.4	52.4	53.6
Adjusted av. final wt., lb.[a]	139.9	141.8	139.8	150.8	143.2
Average daily gain, lb.[b]	1.59	1.60	1.59	1.76	1.64
Feed per lb. gain, lb.	3.14	3.19	3.18	2.99	3.12
13.4–11.1–9.4—protein levels					
Number of pigs	5	5	5	5	20
Average initial wt., lb.	50.0	53.0	52.8	51.2	51.8
Adjusted av. final wt., lb.[a]	137.4	140.2	133.4	137.9	137.5
Average daily gain, lb.[b]	1.48	1.60	1.45	1.51	1.50
Feed per lb. gain, lb.	3.18	3.19	3.45	3.37	3.32
For antibiotic or vitamin B_{12} treatments					
Number of pigs	15	15	15	15	
Average initial wt., lb.	52.1	53.7	54.3	53.3	
Adjusted av. final wt., lb.[a]	140.2	146.5	140.1	145.5	
Average daily gain, lb.[b]	1.56	1.70	1.59	1.68	
Feed per lb. gain, lb.	3.01	3.12	3.18	3.09	

[a] See footnote a, table 3. Regression coefficient, 1.73; mean initial weight, 53.35.
[b] Unadjusted average daily gain.
[c] See footnote c, table 3.

sistent increase in pig weight due to antibiotic at all levels of protein is not consistent with the reports of Catron *et al.* (1952) and Burnside *et al.* (1954). There was an improvement of approximately six percent in efficiency of feed utilization with each two percent increase in level of dietary protein.

Discussion

In neither experiment has a statistically significant improvement in final pig weights been shown to result from the supplementation with chlortetracycline, vitamin B_{12}, or a combination of the two, of rations that contained several levels of protein and that were adequate in non-protein dietary factors. Likewise, protein level combination failed to significantly influence final pig weights in either experiment. There was little disparity between adjusted mean final weights of pigs fed the three protein level combinations in Experiment 1; however, there appeared to be a quite definite trend toward lower adjusted final weights as the reduced protein level combinations were employed in Experiment 2. Only in Experiment 2 was there any indication that experimental treatment influenced efficiency of feed utilization, and in that instance there was approximately a six percent improvement in efficiency of feed utilization with each increase of two percent in protein level combination.

Two factors may have contributed to the tendency toward lighter final weights at the lower protein levels in Experiment 2. The percentage protein in the diets averaged approximately 0.70 percent less than comparable protein level combinations used in Experiment 1. The calculated amino acid content of the rations used in Experiment 2, based on average composition of feedstuffs reported by the National Research Council (1953) and amino acid assays of some of the basic ingredients used in these experiments, may have been less favorable than that of the rations used in Experiment 1. The 14.2 percent crude protein ration used in Experiment 1 would have contained approximately 0.13, 0.25, and 0.65 percent of tryptophan, methionine, and lysine respectively, which figures correspond to 0.92, 1.77, and 4.59 percent of the dietary protein. On the other hand the 13.38 percent crude protein diet used in Experiment 2 would have contained approximately 0.115, 0.28 and 0.55 percent of tryptophan, methionine, and lysine, respectively, which correspond to 0.81, 1.98 and 3.89 percent of the dietary protein. The relative proportion of amino acids would have remained constant in the rations used in Experiment 1 because of the method employed in ration formulation. However, the percentages which tryptophan, methionine, and lysine, respectively, represent of the protein in the 17.5 percent protein ration used in Experiment 2 would have been approximately 0.89, 1.85, and 4.60. Hence, the relative proportion of amino acids would not have remained constant at all levels of protein employed in the second experiment. The lack of consistency

in the relative proportion of amino acids may have played an important role in causing slightly reduced final weights and slightly less efficient utilization of feed for gain at the lower protein level combinations used in Experiment 2. The finding of Almquist (1952) that relative proportion of essential amino acids was a more important attribute than level of protein in the diet tends to support such a suggestion.

The calculated levels of tryptophan, methionine, and lysine in the 14.2 percent protein diet used in Experiment 1 are in good agreement with those reported by Becker *et al.* (1954b) to be adequate for 40 to 100 lb. pigs. However, the amounts of tryptophan and lysine contained in the 13.4 percent crude protein ration used in Experiment 2 are below the levels reported to be adequate by those investigators.

The data reported herein do not support the hypothesis that antibiotics exert a sparing action upon the protein requirement of swine. None of the criteria pointed out by Jensen *et al.* (1955) as necessary to a true sparing action of an antibiotic upon the protein needs of swine has been met. In view of the failure by Brown *et al.* (1952), Braude and Johnson (1953) and Meade (1955) to show an improvement in nitrogen balance of pigs due to chlortetracycline supplementation of the diet this result is not unexpected. The possibility that an antibiotic may spare protein indirectly by virtue of increasing feed intake of pigs fed diets containing lower levels of protein cannot be overlooked. Meade (1955) has shown that growing swine fed a 14.1 percent crude protein diet retained significantly more nitrogen at higher levels of feed intake than at lower levels. Feed intake levels of 2.90, 3.52 and 4.06 percent of body weight were used. Neither chlortetracycline, vitamin B_{12}, nor a combination of the two, caused an improvement in nitrogen retention of growing pigs at either level of feed intake.

Summary and Conclusions

Protein level combinations of approximately 18–16–14, 16–14–12, and 14–12–10 were fed to growing-fattening pigs in rations adequate in non-protein dietary factors. No significant differences resulted in adjusted final pig weight due to level of protein in the diet. In a second experiment slightly lower protein level combinations were employed and protein level again failed to have a significant effect upon final pig weights.

A protein level combination of 14.15–12.17–10.18 percent of the ration was adequate for weanling pigs averaging approximately 38 lb.

when the diet contained calculated levels of 0.13, 0.25, and 0.65 percent of tryptophan, methionine, and lysine, respectively. The differences in amino acid composition of the rations of similar protein content used in the separate experiments were pointed out. The suggestion was made that differences in relative proportion of amino acids in diets of similar protein content may have been a factor contributing to slight, but not significant, differences in final pig weights due to protein level.

Neither chlortetracycline, vitamin B_{12}, nor a combination of the two, exerted a sparing effect upon the protein requirement of pigs used in these experiments. The possible indirect action of antibiotics in sparing protein needs of swine due to increasing feed intake was pointed out.

Literature Cited

Almquist, H. J. 1952. Amino acid requirements of chickens and turkeys—a review. Poultry Sci. 31:966.

Becker, D. E., D. E. Ullrey and S. W. Terrill. 1954a. Protein and amino acid intakes for optimum growth rate in the young pig. JOURNAL OF ANIMAL SCIENCE 13:346.

Becker, D. E., J. W. Lassiter, S. W. Terrill and H. W. Norton. 1954b. Levels of protein in practical rations for the pig. JOURNAL OF ANIMAL SCIENCE 13:611.

Botkin, M. P., A. D. Watts, J. A. Whatley and O. B. Ross. 1951. APF supplements for growing and fattening pigs. Okla. Agr. Exp. Sta. Misc. Pub. No. MP–22–20.

Bowland J. P. and L. W. McElroy. 1952. The effect of antibiotic feed supplements on protein requirements of swine. Report of the 31st Annual Feeders' Day, Dept. of Ani. Sci., Univ. of Alberta, Edmonton, Alberta, Canada.

Braude, R. and B. C. Johnson. 1953. Effect of aureomycin on nitrogen and water metabolism in growing pigs. Jour. Nutr. 49:505.

Brown, P. B., D. E. Becker, S. W. Terrill and L. E. Card. 1952. The effect of aureomycin on the growth and metabolism of the pig. Arch. Biochem. and Biophys. 41:378.

Burnside, J. E., R. H. Grummer, P. H. Phillips and G. Bohstedt. 1954. The influence of crystalline aureomycin and Vitamin B_{12} on the protein utilization of growing-fattening swine. JOURNAL OF ANIMAL SCIENCE 14:184.

Catron, D. V., A. H. Jensen, P. G. Homeyer, H. M. Maddock and G. C. Ashton. 1952. Re-evaluation of protein requirements of growing-fattening swine as influenced by feeding an antibiotic. JOURNAL OF ANIMAL SCIENCE 11:221.

Cunha, T. J., J. E. Burnside, H. M. Edwards, G. B. Meadows, R. H. Benson, A. M. Pearson and R. S. Glasscock. 1950. Effect of animal protein factor (APF) on lowering protein needs of the pig. Arch. Biochem. 24:455.

Geurin, H. B., J. A. Hoefer and W. M. Beeson. 1951. Protein efficiency of corn by-products and other protein feeds for swine growth. JOURNAL OF ANIMAL SCIENCE 10:607.

Hanson, L. E., E. F. Ferrin and S. N. Singh. 1955. The influence of arsanilic acid on protein requirements of growing pigs. JOURNAL OF ANIMAL SCIENCE 14:525.

Hoefer, J. A., R. W. Luecke, F. Thorp, Jr. and R. L. Johnston. 1952. The effect of terramycin on the growth of pigs fed different levels of protein. JOURNAL OF ANIMAL SCIENCE 11:455.

Jensen, A. H., D. C. Acker, H. M. Maddock, G. C. Ashton, P. G. Homeyer, E. O. Heady and D. V. Catron. 1955. Different protein levels with and without antibiotics for growing-finishing swine: Effect on growth rate and feed efficiency. JOURNAL OF ANIMAL SCIENCE 14:69.

Jukes, T. H., E. L. R. Stokstad, R. R. Taylor, T. J. Cunha, H. M. Edwards and G. B. Meadows. 1950. Growth promoting effect of aureomycin on pigs. Arch. Biochem. 26:324.

Lassiter, J. W., S. W. Terrill, D. E. Becker and H. W. Norton. 1955. Protein levels for pigs as studied by growth and self-selection. JOURNAL OF ANIMAL SCIENCE 14:482.

Meade, R. J. 1955. The influence of amino acids and other dietary factors upon nitrogen utilization by growing swine. Ph.D. thesis. University of Illinois.

National Research Council. 1953. Nutrient requirements for domestic animals. No. 2. Nutrient requirements for swine.

Robison, W. L. 1952. Ohio Agr. Exp. Sta. Mimeo. Series. Swine 77:4.

Snedecor, G. W. 1946. Statistical methods applied to experiments in agriculture and biology. 4th edition. Iowa State College Press, Ames, Iowa.

PORTABLE UNITS FOR INDIVIDUAL EXPERIMENTAL PIG FEEDING ON PASTURE [1]

G. C. ASHTON, D. V. CATRON, P. G. HOMEYER,[2]
N. H. CURRY [3] AND C. C. CULBERTSON
Iowa Agricultural Experiment Station

ANALYSES of data from pasture experiments with swine fed various rations frequently do not show statistically significant differences between the performances made on the rations under test because of large experimental errors or insufficient replication of the treatments. These experimental errors are usually larger than those obtained in drylot feeding trials because of such additional sources of variability as yield, nutritive value, and palatability of the forage consumed by the pigs from the different areas of the test plots. With the usual techniques employed in swine pasture research the resources—land, equipment, experimental material, labor, etc.—are frequently insufficient to provide adequate numbers of pigs per pasture treatment and the number of replicates of each pasture treatment for the experimental precision desired.

Frequently the testing of swine rations on pasture has been carried out using as many as ten pigs per treatment and an area of one acre in size for each treatment. To replicate such a set-up only once with six to ten ration treatments per replication requires from 12 to 20 acres of land, from 120 to 200 head of hogs and approximately $600 per experimental unit (group of 10 pigs) for necessary fencing, shelters, feeding and watering equipment.

In order to find possible methods for increasing the precision of pasture experiments that fulfill the requirements for proper statistical analyses of responses, the statistical model shown in table 1 is useful. Consider swine feeding experiments on pasture in which there are r rations, p pastures per ration, and a animals per pasture. Assuming that the pigs are assigned to the pastures at random, that the gains of pigs within pastures are independent of one another, that the rations are

[1] Journal paper No. J-2768 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 930.
[2] Department of Statistics.
[3] Department of Agricultural Engineering.
Acknowledgment is made to Mr. Don Quinn, Swine Nutrition Research Farm, for his assistance.

assigned at random to the pastures, and rations are fixed factors the model for an analysis of variance of gains is obtained. The symbol μ_i is the true mean gain on the i^{th} ration and μ is the mean of the μ_i's. The variance of a ration mean gain is estimated by $\frac{s_A^2}{ap} + \frac{s_P^2}{p}$ where s_A^2 and s_P^2 are estimates of σ_A^2 and σ_P^2 respectively. In general σ_P^2 is not negligible and in many grazing experiments is large relative to σ_A^2. Consequently s_A^2 usually does not provide an unbiased estimate of experimental error. In addition, a single pasture per ration confounds ration gains with pastures.

The formula in table 1 shows that for a fixed number of animals the

TABLE 1. ANALYSIS OF VARIANCE MODEL

Source of variation	Degrees of freedom	Mean square	Expected mean square
Rations	(r–1)	R	$\sigma_A^2+\sigma_P^2+ap\sum_{i=1}^{\mu}(\mu_i-\mu)^2/(r-1)$
Pastures within rations	r(p–1)	P	$\sigma_A^2+\sigma_P^2$
Animals within pastures	rp(a–1)	A	σ_A^2.

variance of a ration mean gain is minimized by maximizing the number of pastures per ration and thereby using a single animal per pasture. Also, increasing the number of pastures per ration increases the number of degrees of freedom for estimating the experimental error.

Two objections given to individual feeding, in drylot or on pasture, are that cost is increased and that most species of animals will gain weight at a slower rate than when group fed. Although individual feeding is usually more costly per animal than group feeding, in some instances it may provide more information per dollar spent. With respect to gain, the important question is whether there is an appreciable interaction of the two methods of feeding with mean gains on different rations. Only limited evidence is available in the literature that such an interaction is generally important.

Therefore, in an attempt to increase efficiency relative to the resources used, we directed our attention towards devising equipment which would permit feeding and management of the pigs individually.

It was also considered important to devise equipment with a high degree of flexibility.

Experimental Equipment

Compared to a cost of $600 per experimental unit (10 pigs per unit) given above for fixed facilities, consideration of fencing fixed pen space equipped with portable shelters, feeders and waterers yielded an estimate of $250 per experimental unit using one pig per unit in one-tenth acre lots. A serious objection to this arrangement is the difficulty in rotation of small areas of land. A completely portable arrangement where the necessary partitioning, shelter accommodation, feed and water facilities were included was estimated to cost $200 per experimental unit (1 pig per unit).

Figure 1 presents several features of a 3-pen structure. The structure is 16 feet square which gives individual pen measurements of 5 ft. 4 in. $\times$ 16 ft. The dimensions of the doorway of each pen are 2 ft. 10¼ in. $\times$ 2 ft. 10¾ in. The unit has as integral parts outside-filled self-feeders, float-operated waterers and a 30-gallon water reservoir. It is light enough to be moved about with ease by a tractor of average size. The nature of the materials used in construction and the manner of joining the several parts gives a resilience to the framework which permits it to follow the land contours rather closely without undue stress on the joints of the structure.

The unit rides on 4 $\times$ 4 in. wooden runners, one under each of the four partitions. To the end of each runner is fastened a broad S-shaped flat strap iron to which a chain from a tubular metal drawbar is hooked (figure 1-upper). Substitution of the rigid bar by chains only, will put undue stress on the structure.

Figure 1-lower shows in some detail the 2 $\times$ 4 in. lumber frames, 38 in. in height with the lower 12 in. made solid with ⅜ in. exterior grade plywood glued to the framework and the upper portion of the three sides and partitions covered with 2 $\times$ 4 in. welded wire fabric. The glued plywood sheets prevent contamination of an adjoining pen with feed, feces or urine by any one pig. They also serve as a source of the spring-like structural action obtained from the frames. To give support while moving, the two inner partitions are fastened to the cross member by diagonally attached strap irons. The opposite end is solid and needs no such support. The fourth side of the unit is made solid in its entirety for supporting the load of the water tank, waterers, and self-feeders.

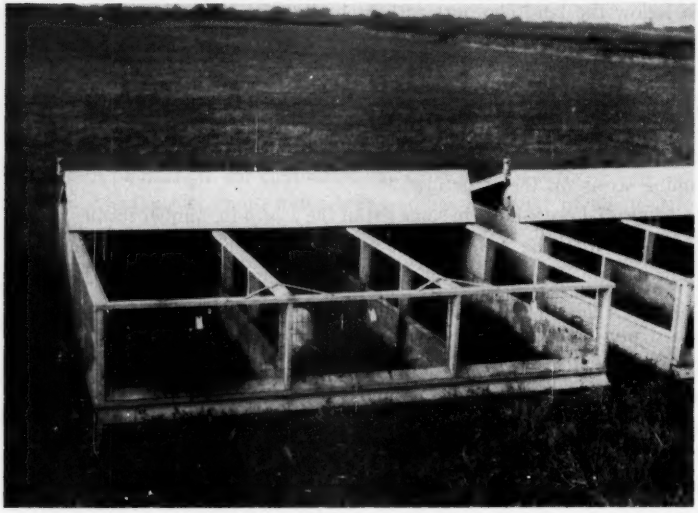


Figure 1. Photographs of different aspects of a 3-pen unit. Upper. A 3-pen unit; Lower. Detail of construction of a 3-pen unit.

Twelve-inch-square wire-covered portholes are provided for each pen to allow for air circulation and to control drafts (figure 1).

They can be propped up to permit freedom of air movement and to

Figure 2. The self-feeder in position for filling or weighing.

provide supplemental shade when the sun is low, or they can be dropped and fastened to form the 2nd and 3rd side of a solid 3-wall compartment shelter.

The roof frame is constructed of 2 × 4 in. lumber and covered with

0.024 in. sheet aluminum. This material reduces weight and has proved effective in reducing summer temperatures.

Each pen has a heavily built and strongly hinged door of plywood glued to each face of a wood frame to serve as a swinging hanger for the self-feeder. This provides easy access to the feeder by simply swinging the door outward and the same door is used for removal of the pig when necessary.

Figure 2 is a view of the feeder as it is made accessable for filling or weighing by opening the door upon which it hangs. The step at the bottom is to enable the smaller pigs to reach the trough of the feeder, the top of which is 8 in. from the ground.

The feed and pigs are weighed on a beam scale fastened to a tractor lift. At weighing time the feeder is attached directly to the scale while the pigs are placed in a crate suspended from it.

The working drawings, directions for construction and bill of materials for a 3-pen unit will be furnished by the authors upon request.

Experimental Designs

The type of experimental design which may be used and the number of rations which may be tested with reasonable precision depends in part upon the number of units available. A set of twelve 3-pen units which accommodate 36 individually-fed experimental animals permits the use of several types of experimental designs which include completely randomized, randomized blocks, split-plot, latin square and several of the incomplete block designs. A possible random arrangement for each of three experimental designs, randomized block, split-plot and balanced lattice is given in figure 3.

The plan given for the randomized block design (figure 3-A) is for six rations. Each block consists of two adjoining 3-pen units. To take advantage of this design for increasing precision, the six groups of six pigs each should be selected from the pigs available in such a way as to minimize the variation among pigs within groups with respect to characteristics that influence experimental response. With only six experimental rations, it is desirable to use littermates within groups where possible. The six groups of pigs are randomly assigned to the blocks and the pigs within groups are assigned at random to the pens. The rations are then assigned at random to the pens within each block.

Figure 3-B presents a randomized plan for a 3×2 factorial experiment in a split-plot design. The nutritional factor at three levels might represent three levels of protein and the factor at two levels might

represent two levels of an antibiotic. The main object of the experiment might be to study the response to the levels of protein and the interaction of protein level with the antibiotic. Further a sufficient number of litters with six or more pigs each is not always available, but a sufficient number of groups of three littermate pigs might be available.

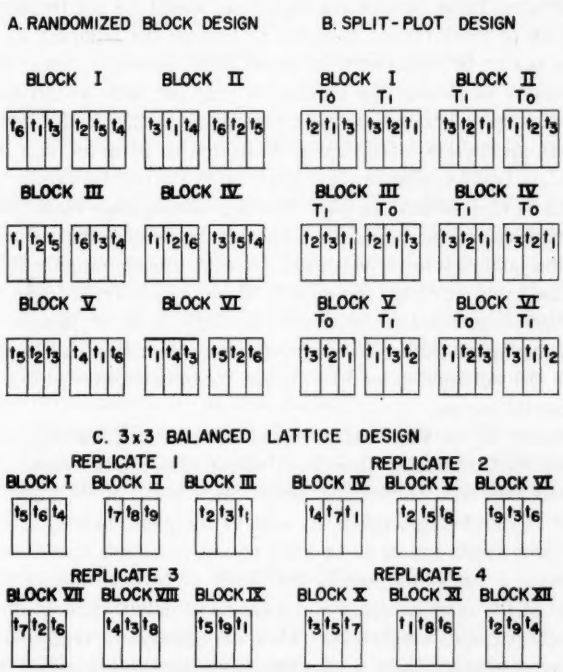


Figure 3. Schematic arrangement of 3 possible experimental designs.

Also, with groups of only three pigs it is frequently possible to obtain pigs of both the same sex and litter within groups. Under such conditions the split-plot design is quite useful. Each block consists of two 3-pen units and the pigs in one unit receive antibiotic and those in the other do not. The pigs within a 3-pen unit each receive a different level of protein. The estimates of differences in mean gains of pigs receiving different levels of protein would be expected to have greater pre-

cision than the estimate of the mean differences in gain of pigs receiving no antibiotic and those receiving antibiotic.

In incomplete block designs the experimental units are arranged in blocks that do not include a complete replicate. This is done to reduce the experimental error more than would be possible with randomized block designs. These designs are sometimes useful for pig feeding trials with seven or more rations in order to remove the influence of litters from estimates of differences in mean gains among rations. With a large number of rations the number of pigs per litter is too small to use randomized block designs with littermates within each block. The particular incomplete block design illustrated in figure 3c is a 3×3 balanced lattice for nine rations. Each replicate contains three incomplete blocks each with three pigs. The pigs within each block could be littermates and might be of the same sex to remove the influence of both litter and sex in estimating differences among ration effects.

The flexibility of design afforded by these units permits ready testing of multiple supplemental rations on a single type of pasture or on different pastures swards. With less efficiency the units may be used to measure the nutritive value of different pastures swards with a single supplemental ration.

By reason of the fact that the feces of the individual pigs may be identified when voided in these units, digestibility studies under pasture conditions take on a challenging aspect. As a result of the achievement attained in developing organic as well as inorganic indices of digestibility, there would appear to be good reason to believe that these units might serve a useful purpose in the study of herbage digestibility by pigs and at the same time provide a means of determining quantitative consumption of pasture herbage. They may provide a ready means of determining whether there is an associative digestibility effect between herbage and dry feed. They also offer an opportunity for the animal breeder to obtain record-of-performance data for individual pigs under pasture conditions for different genetic combinations.

Summary

A portable 3-pen combination shelter-pen structure that can be employed for individual experimental pig feeding on pasture has been described.

The use of such structures in several statistical designs which provide for valid statistical analyses of the experimental response data, e.g. body weight gains, feed consumption, etc., has been indicated.

COMPARISON OF REFINED CANE SUGAR, INVERT CANE MOLASSES AND UNREFINED CANE SUGAR IN STARTER RATIONS FOR EARLY WEANED PIGS [1, 2]

J. Diaz, V. C. Speer, G. C. Ashton, C. H. Liu and D. V. Catron [3, 4]

Iowa Agricultural Experiment Station

SUGAR has been established as a desirable ingredient for increasing early consumption of pre-starter and starter rations by baby pigs weaned at ages varying from one to eight weeks of age.

Nelson *et al.* (1953) first demonstrated the value of cane sugar for baby pigs. Later Lewis *et al.* (1953) showed that pig performance increased with increased levels of sugar up to 20 percent of the total ration. The value of sugar for increasing the palatability of pig starters has since been confirmed by McMillan *et al.* (1954), Hanson *et al.* (1954) and Jensen *et al.* (1955). The latter two groups of workers found that saccharin failed to improve feed consumption and pig performance when compared to cane sugar.

The purpose of this experiment was to try to establish a cheaper source of sugar in starter rations for early weaned pigs, without affecting the palatability, nutritional value and general performance of the ration.

Experimental

One hundred and twenty Hampshire x Landrace baby pigs averaging, initially, 9 days of age and 5.8 lb. in weight were used in this experiment. The ten ration treatments tested and their arrangement in the design are shown in table 2. Because litters with less than ten pigs each were available, the pigs were allotted to the experiment with the restriction that only one pig from a litter could receive each ration. Ten pens of four pigs each were allotted, one pen to each ration, at three-day

[1] Journal paper No. J-2808 of the Iowa Agricultural Experiment Station, Ames, Iowa. Animal Husbandry Department. Project No. 959.

[2] This research was supported in part by two grants, one from the Sugar Research Foundation, 52 Wall Street, New York 5, N. Y., and another from the Publicker Industries, Inc., Philadelphia, Pa.

[3] The authors appreciate the vitamins and antibiotics supplied by Fine Chemicals Division of the American Cyanamid Co., New York, N. Y. and Merck and Co., Inc., Rahway, N. J., and the unrefined cane sugar supplied by E. R. Squibb & Sons, Inc., New Brunswick, N. J., and invert cane molasses supplied by Publicker Industries, Inc., Philadelphia, Pa.

[4] Acknowledgment is made to Mr. Donald Quinn, Swine Nutrition Research Farm superintendent and his associates for their assistance.

intervals to provide three replications for each ration treatment. A pen of four pigs was used as the experimental unit in partitioning the variation of the response criteria into the several portions shown in the analysis of variance plan below.

ANALYSIS OF VARIANCE PLAN

Source of variation	Degrees of freedom
Replication	2
Ration treatment	9
Remainder	18
All causes	29

The pigs were housed in a 65° F. heated insulated tile building with concrete floors. Heat lamps were used to provide restricted space heating starting at 80° F. five inches off the floor for the first 4 weeks of age. Heat lamps were then replaced by 40 watt light bulbs to furnish continuous light. The pigs were self-fed and fresh water was furnished by automatic founts which were flushed daily. Careful sanitation was practiced, pens were cleaned daily and wood shavings were used for bedding. At the beginning of the experiment all pigs were given a reduced-iron pill and they were vaccinated with a mixture of hog cholera and erysipelas serums. Permanent immunity to hog cholera was given at 5 weeks of age. Pig weight and feed consumption records were made weekly.

All pigs were fed I.S.C. Pig Pre-Starter "75", Speer *et al.* (1954),

TABLE 1. COMPOSITION OF THE BASAL STARTER RATION[a]

Ingredients	Percent
15.5% rolled oat groats	40.00
8.77% ground yellow corn	33.15
60% fish meal (Menhaden)	2.50
12% dried whey (low lactose)	2.50
34% dried skimmilk (low heat, spray dried)	10.00
46.13% solvent soybean oil meal (blended)	8.00
Ground limestone	0.85
Dicalcium phosphate	2.30
Iodized salt	0.50
Trace mineral premix (CCC—swine)	0.20
Total	100.00

[a] Calculated analysis: Crude protein 18 percent; fat 3 percent; fiber 2.4 percent; calcium 1.25 percent; phosphorus 0.85 percent; crystalline vitamins were added to supply the following calculated amounts per pound: vitamin A 5220 I.U.; vitamin D_2 500 I.U.; riboflavin 4 mg.; calcium pantothenate 8.3 mg.; niacin 26.6 mg.; choline chloride 482 mg.; vitamin B_{12} 20 mcg.; and chlortetracycline 50 mg.

for one week to assure more uniformity in starting on dry feed. Then they were switched to and fed their pre-determined experimental starter rations from 2 to 8 weeks of age. The basal starter ration and the 9 modifications thereof are shown in tables 1 and 2, respectively. The reason for restricting the experimental design was to limit the

TABLE 2. EFFECT OF LEVELS OF REFINED CANE SUGAR AND/OR LEVELS OF SUGAR FROM INVERT CANE MOLASSES AND UNREFINED CANE SUGAR IN PIG STARTERS

Data	Refined cane sugar, percent				Sugar from invert cane molasses
	0	5	10	15	
	lb.	lb.	lb.	lb.	%
2 Wk. wt.	7.2	6.9	7.0	7.6	
8 Wk. wt.	41.8	41.9	45.0	47.3	
Av. daily gain [a]	0.74	0.74	0.80	0.84	0
Daily feed pig	1.30	1.31	1.40	1.42	
Feed/lb. gain [a]	1.77	1.77	1.75	1.70	
2 Wk. wt.	7.2	7.1	7.2		
8 Wk. wt.	40.7	43.4	45.5		
Av. daily gain	0.71	0.76	0.81		5
Daily feed pig	1.26	1.39	1.45		
Feed/lb. gain	1.77	1.82	1.82		
2 Wk. wt.	6.9	7.0			
8 Wk. wt.	42.3	44.5			
Av. daily gain	0.74	0.79			10
Daily feed pig	1.32	1.35			
Feed/lb. gain	1.77	1.71			
2 Wk. wt.				7.3	
8 Wk. wt.				47.3	Unrefined
Av. daily gain				0.85	cane sugar
Daily feed/pig				1.42	
Feed/lb. gain				1.67	

[a] Increase in daily gain and decrease in feed per lb. of gain with increasing cane sugar content of rations significant at P 0.05 or less (9 to 56 days).

amount of total sugar coming from any single source or combination of sources to 15 percent. This is about the maximum amount that can be pelleted in practical, modern, pig starter formulas. The starter rations were fed as 3/16 inch pellets. The invert cane molasses contained 76 percent sugar equivalent and it was added at two levels to supply the equivalence of approximately 5 and 10 percent sugar. Variable proportions of corn and soybean oil meal were substituted for refined sugar, invert cane molasses or unrefined cane sugar to maintain a

constant protein level in all rations. A constant level of added minerals, vitamins and antibiotics was maintained in all rations.

Results and Discussion

Both gains and feed efficiency were significantly improved as the level of refined cane sugar increased from 0 to 15 percent. This is in agreement with the previous findings of Lewis *et al.* (1953) and Jensen *et al.* (1955). The addition of sugar from invert molasses alone failed to improve pig performance. Neither did it show significant additive effects when added to refined sugar. Unrefined cane sugar produced gains and feed efficiency equal to refined cane sugar when each were singly fed at the 15 percent level. The use of unrefined sugar should result in considerable savings to hog producers.

Neither calorific determinations of the 10 different experimental rations with the bomb calorimeter, which gave values from 4.153 to 4.280 calories per gram, or total ash content of the rations showed any trends which would help explain the results in pig performance. Therefore, the improved gains due to the increased levels of refined cane sugar in the rations may be the result of increased daily feed intake, improved metabolism of other nutrients or both. Further research is needed to elucidate the causes of these effects.

No excessive scouring attributable to the addition of refined sugar, invert molasses, or unrefined cane sugar, at the levels fed, was evident during the experiment.

Summary

One hundred and twenty baby pigs weaned at an average of 9 days of age and 5.8 pounds were all fed I.S.C. Pre-Starter "75" to 2 weeks of age. Then they were used to evaluate rations containing 0, 5, 10 and 15 percent sugar coming from refined cane sugar; 0, 5 and 10 percent sugar from invert cane molasses; or combinations of the two sugars not to exceed 15 percent total sugar. These rations were compared to one containing 15 percent unrefined cane sugar. Triplicate pens of 4 pigs each were fed the 10 different experimental rations from 2 to 8 weeks of age.

Increased levels of refined cane sugar and unrefined cane sugar, but not sugar from invert cane molasses, improved gains and feed efficiency. No excessive scoring was noticed attributable to sugar or molasses at the levels fed.

Literature Cited

Hanson, L. E., E. A. Rutledge, J. M. Russo and E. F. Ferrin. 1954. Dry rations for pigs weaned at three weeks. Minn. Agr. Exp. Sta. Mimeo. H–124.

Jensen, A. H., J. E. Launer, S. W. Terrill and D. E. Becker. 1955. Palatability of starter rations for suckling pigs. Univ. of Ill. Mimeo. AS-418.

Lewis, C. J., D. V. Catron, G. E. Combs, Jr., G. C. Ashton and C. C. Culbertson. 1953. Cane sugar in pig starters. JOURNAL OF ANIMAL SCIENCE 12:923.

McMillan, F. A. and H. D. Wallace. 1954. Palatability studies on creep feed formulations for suckling pigs. JOURNAL OF ANIMAL SCIENCE 13:39.

Nelson, L. F., L. N. Hazel, A. A. Moore, H. M. Maddock, G. C. Ashton, C. C. Culbertson and D. V. Catron. 1953. Baby pigs have a sweet tooth. Iowa Farm Sci. 7:3.

Speer, V. C., G. C. Ashton, F. Diaz and D. Catron. 1954. New I.S.C. pre-starter "75". Iowa Farm Sci. 8:3.

RECORD OF THE PROCEEDINGS OF THE FORTY-SEVENTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The 47th annual meeting of the American Society of Animal Production was held in Hotel Sherman, Chicago, Illinois, on November 25–26, 1955. Abstracts of most of the papers presented were published in the November, 1955 issue of the JOURNAL OF ANIMAL SCIENCE, Vol. 14, pp. 1174–1262.

INTRODUCTORY REMARKS

GENERAL SESSION—AMERICAN SOCIETY OF ANIMAL PRODUCTION

J. I. MILLER

Even though these meetings have been underway since 9:30 a.m., we wish at this time to extend greetings and welcome to both members and non-members alike that are in attendance at this 47th Annual Meeting of the Society. It is obvious that you will again find these meetings important to your activities in any of the broad or specialized fields of animal husbandry.

You have, of course, noticed several important changes from the usual program. For example, this general session has been shortened in order to provide more time for presentation of research papers. Your Executive Committee made this decision a year ago due to the large number of papers being submitted and to the probability of more, rather than fewer papers being submitted in the future.

There were sound arguments for providing more sections. The number of papers submitted during the pre-war period was approximately 75 while the number of papers submitted this year totaled 211. I am sure the Executive Committee will continue to review the program situation each year and will welcome your suggestions at any time.

Then, we regret to call your attention to the fact that we do not have this year an Honor Guest with the presentation of his portrait to the Saddle & Sirloin Club. This matter, again, has been under discussion for a number of years. Actually, the Portrait Committee of the

Club has given us the privilege of an annual presentation for a longer period than it had once believed possible. However, upon receiving notification of the definite change in policy your Executive Committee asked for a reconsideration. Our arguments were presented most ably by Dean A. E. Darlow and by Dean A. D. Weber. Dean Emeritus H. H. Kildee, a member of the Portrait Committee, was also very helpful. We can assure you that the Portrait Committee of the Club will give Society nominees every consideration possible and that we will have honor guests in the future even if not on an annual basis.

The excellent status of the Society will, of course, be covered in the business session. However, it seems entirely appropriate for us to direct recognition at this time to the splendid work of the various officers, committeemen, special representatives, the Editorial Board of the JOURNAL OF ANIMAL SCIENCE, and especially to the work of the Secretary-Treasurer and the Editor.

A glance at the program for this meeting is ample evidence of the enormous effort, skill, and leadership the members of this Society exert in all fields affecting efficiency in animal production. We know the results of such effort will continue to aid in making livestock farming still more efficient and more profitable.

It is no doubt disturbing to many members of this Society to face the issue of agricultural surpluses with the resulting government program of buying and storage; price supports and acreage controls; and the other possible Federal programs now being discussed that would limit production. However, no agricultural topic is of greater current interest and we need factual information to understand the problems. The talk at this general session will be on the current and expected supply and demand situation for livestock and possibly other agricultural products.

Our scheduled speaker, Dr. Paarlberg, chose the concise title, "Can We Eat All We Can Produce." Our actual speaker has kept the same title.

Mr. Harold F. Breimyer is an agricultural economist, trained at Ohio State University. He has been with the U.S.D.A. for approximately 20 years and is in the Agricultural Marketing Service. For the past 8 years he has been in charge of the Outlook Report, Livestock and Meats Section, and therefore could hardly be better qualified to discuss this subject.

A SUMMARY OF THE MINUTES OF THE FORTY-SEVENTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

W. M. BEESON, *Secretary*
Purdue University

The meeting was called to order in the Louis XVI Room of the Hotel Sherman, Chicago, Illinois, on November 26, 1955, at 2:30 p.m. by President J. I. Miller. The minutes of the 1954 Business Meeting were not read but were approved as published in the JOURNAL OF ANIMAL SCIENCE, Vol. 14: pp. 303–312.

The report of the Secretary was as follows:

"The American Society of Animal Production continues to grow in size with a total of 1509 members, which is an increase of 165 members over 1954. Members of the Society are scattered throughout the world with the following distribution: 1457 United States and Canada; and 52 Foreign. The Membership Committee has done an excellent job of encouraging young men engaged in the Animal Sciences to join the Society. Through the work of the committee 227 new members have been accepted by the Society this year. According to our records, there are still quite a few people that attend the Annual Meeting who are not members of the Society but are eligible for membership. Also a few individuals who are co-authors of papers are not members.

"Subscriptions to the JOURNAL OF ANIMAL SCIENCE have increased significantly (124 more) with a total of 1136. In this total, 511 were domestic and 625 foreign. Foreign subscriptions are increasing each year and it is of special interest that the JOURNAL is sent to 50 different foreign countries. JOURNALS are being mailed quarterly to 2,645 individuals, libraries and business firms. Address changes should be sent promptly to the office of the Secretary to avoid delay in receiving the current issue of the JOURNAL.

"During the year the office of the Secretary has sent three form letters to the entire membership and has mailed two letters to each subscriber. In response we have received about 4500 letters plus the usual correspondence necessary in the conduct of the business concerning the Society and the JOURNAL.

"There were 211 papers submitted and 169 were presented on the program, and the remainder (42 papers) were listed by title. Starting the sectional meetings in Breeding and Genetics, Nutrition and Physiology on Friday morning has permitted 28 more papers to be given as compared to last year.

"As Business Manager for the JOURNAL, I wish to express my appreciation to our new Editor, J. K. Loosli, and to the Boyd Printing Company for the fine quality of their work.

"The officers, the various committees and the contributors of papers are to be commended for submitting their material on time and for the preparation of an

excellent program. Personally I want to thank all members of the Society for their fine support and prompt reply to business concerning the Society."

The Treasurer and Business Manager of the Society, W. M. Beeson, presented the following report:

"The balance for the General Society Fund shows an operating gain of $4,753.65 for the fiscal year ending October 31, 1955. This year's net gain in the General Fund was less than last year by $452.42, which was primarily due to increase in cost of printing and mailing the JOURNAL.

"Operating expenses for the Society are increasing each year. The total General Fund expenses for this year were $22,179.07 as compared to $19,346.07 for last year. The total income for the General Fund was $26,932.72. The income from the Morrison Award Fund was $1,926.69 and expenditures amounted to $1,430.10, showing a net gain of $496.59.

"The cash balance on hand in the General Fund ($19,422.13) plus the Morrison Award Fund ($3,323.82) at the close of this fiscal year was $22,745.95. In addition, the Society has assets of $15,106.00 in U. S. Government Bonds—Series G, F and J. Thus, the total tangible assets of the Society as of October 31, 1955, were $37,851.95.

"As Treasurer and Business Manager, I want to thank each member for his fine cooperation in prompt payment of dues, arranging for reprint payments and for accurate notification of changes of address."

Auditing of the financial records of the Society for the period November 1, 1954 to October 31, 1955 was made by Certified Public Accountants, D'Aoust and Golliher of Lafayette, Indiana.

President J. I. Miller read part of this auditing report and stated that the detail records are on file in the Treasurer's office for examination. In part the report was as follows:

"In our opinion, the accompanying statement of assets and liabilities and the related statements of income and expense, and fund balance and net worth present fairly the recorded financial position of American Society of Animal Production at October 31, 1955, and the results of its operations for the year then ended."—Signed D'Aoust and Golliher.

The Editor of the JOURNAL OF ANIMAL SCIENCE, J. K. Loosli, gave the following report:

"In volume 14 of the JOURNAL there were published 129 original scientific articles, 211 abstracts of papers presented at the 1955 annual meeting of the Society, proceedings of the 1954 meeting, author and subject indexes for volume 14 and the News and Notes Section in each issue.

"A total of 162 manuscripts were received during the period from November 16, 1954 until November 15, 1955. This makes a total of 1238 papers which have been considered for publication in the JOURNAL since its beginning 14 years ago. Of

those received during the past year 10 have been withdrawn or rejected, 95 have been published, 35 are in press for the February, 1956 issue, 8 are being revised by the authors and 12 are being reviewed by the Editorial Board.

"The term of L. N. Hazel expires on December 31, 1955. The Executive Committee has appointed L. E. Hanson and O. G. Bentley to the Editorial Board.

"Your Editor wishes to express his sincere appreciation to L. N. Hazel for his invaluable services on the Editorial Board and to the other members of the Society who have assisted by reviewing papers."

The records of the Business Manager of the JOURNAL OF ANIMAL SCIENCE listed the following back numbers of the JOURNAL available for sale:

Vol.	Year	Complete Volumes	Number of Copies in Single Issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	0	0	9
2	1943	0	21	11	0	0
6	1947	0	0	1	0	2
7	1948	2	3	2	3	2
8	1949	0	0	0	1	3
9	1950	1	2	1	51	53
10	1951	1	3	92	1	46
11	1952	1	2	1	74	132
12	1953	44	63	98	82	44
13	1954	290	290	311	326	393
14	1955	126	126	146	155	155

These back numbers may be purchased from the Business Manager at the following rates: Volumes 10–14, $1.75 per single copy for domestic and $2.00 for foreign; for preceding issues, $1.25 and $1.50, respectively. In addition, the following proceedings of the American Society of Animal Production may be purchased at a cost of $1.00 each for domestic and $1.25 for foreign:

Year	No. of Copies	Year	No. of Copies
1915–16	48	1931	60
1922	446	1932	19
1923	229	1933	39
1925–26	39	1934	25
1927	46	1935	30
1928	1	1938	1
1929	30	1940	47
1930	16		

W. A. Craft of the Nominating Committee proposed the names of L. E. Casida for President and W. M. Beeson for Secretary-Treasurer. These men were elected by unanimous vote. Nominees for the Vice-President were J. C. Miller and J. E. Foster. Ballots were distributed for voting by L. H. Blakeslee, W. W. Green, and A. B. Nelson.

The report of the Committee on Research was given by L. E. Johnson:

"The Research Committee was instructed by the President of the American Society of Animal Production to (1) study and edit all technique materials prepared and presented by the Monograph Committee, (2) consider a request to recommend essential characteristics of the desirable beef animal, alive and its carcass, with an optimum of fat, together with suggestions for research and action required for the adoption of a standard, or standards, and (3) suggest other research matters needing attention of the Society.

"No material was received from the Monograph Committee. The Research Committee regrets the delay in the completion of the Monograph material and wishes to recommend that the Executive Committee encourage publication by the Monograph Committee in 1957 to the extent of finding some money for the work if such is needed to bring conclusion to the project. With many new men joining our research staff, the material is needed now.

"To set up standards for an ideal beef animal appeared to demand more facts than were possessed by the Research Committee at this time. The Committee wishes to suggest that the Executive Committee of the Society give consideration for conducting a symposium at our next annual meeting on the available information on essential characteristics of meat animals both alive and in the carcass with emphasis on probable standards for the foreseeable future. Following the symposium it is suggested that a committee be considered to outline needed research in the fields of consumer demand, production standards and grading practices.

"The Research Committee believes that further coordination of breeding, feeding, and management studies with carcass values is greatly needed and wishes to recommend consideration of this in many projects during the next few years."

Monograph Committee report was read by C. E. Terrill:

"The Monograph, "Techniques and Procedures in Animal Production Research" is nearing completion. The sections on Nutrition, Meats and Physiology have been completed for some time. The section on Design and Analysis of Animal Husbandry Experiments was completed in July. The section on Animal Breeding is not yet complete but the author has promised the manuscript by December 20, 1955. It is anticipated that final arrangements for publication can be made by Spring (May 1)."

J. A. Hoefer stated that the Teaching Committee had no report to make to the Society.

The report of the Committee on Information was given by Carl F. Neumann:

"As usual the Committee on Information has prepared news releases covering high points of the Society meeting. These are being made available to the nation's agricultural press—to a number of radio stations—to the Chicago City News Bureau, Chicago papers and to the press wire services.

"The press wire services include the Associated Press, the United Press and the International News Service. These services relay news stories to daily and weekly papers.

"The agricultural publications contacted include livestock market papers, farm papers, cattle, hog and sheep publications, and general livestock papers.

"Regarding the results accruing from the work of the Committee on Information last year, let me say that it is not possible to fully check the coverage. Information on hand, however, and of necessity, not complete, shows that agricultural papers, and daily and weekly papers of 13 different states used one or more stories. These publications have a total circulation of 3 million, 100 thousand. Among leading daily papers using news stories from last year's meeting were the Chicago Daily News, the Chicago Tribune, Seattle Post Intelligencer, Buffalo New York News, and Syracuse, New York, Herald American."

W. J. Loeffel recommended that the Society express our appreciation to The National Livestock and Meat Board and especially to Howard Biggar and Carl F. Neumann for their fine work in publicizing the affairs of the Society.

W. G. Kammlade reported for the Necrology Committee and recommended that the following memorials be published in the JOURNAL OF ANIMAL SCIENCE: Arwed C. Baltzer, George Arthur Brown, Ralph Boyd Cathcart, Harry Sands Grindley, Herman Lauritz Ibsen, and Frank Thorp, Jr. This report was accepted with a minute of silent prayer in remembrance of these members.

E. J. Warwick gave the following report for the Resolutions Committee:

"BE IT RESOLVED that the membership of the Society express appreciation to Prof. and Mrs. F. B. Morrison for their continued interest and generosity in providing the annual Morrison Award.

"BE IT RESOLVED that the Society express its appreciation to the American Feed Manufacturers Association for its continued interest in and recognition of outstanding research accomplishments of Society members.

"BE IT RESOLVED that the membership of the Society express its appreciation to the officers, the editor of the JOURNAL OF ANIMAL SCIENCE and the editorial board of the JOURNAL for their efforts in handling the affairs of the Society so ably during the past year.

"BE IT RESOLVED that this Society go on record as commending the American Meat Institute, The National Livestock and Meat Board, The American National Cattleman's Association, The National Swine Growers Council, The American Sheep Council, American Dairy Association and other state and national livestock organizations for their efforts in promoting the expanded consumption of animal products and in supporting research in both production and marketing.

"BE IT RESOLVED that the Society express its appreciation to H. H. Biggar and Carl Neumann of the National Livestock and Meat Board for their time and effort expended in publicizing the Society proceedings.

"BE IT RESOLVED that the Society express its appreciation to the Sherman Hotel for the meeting facilities provided."

T. C. Byerly submitted the following report as a representative to the American Association for the Advancement of Science:

"I wish to call attention to three significant events sponsored by American Association for the Advancement of Science. The first of these is the symposium on air pollution at Berkeley, California, in 1954. Concentration of attention on the problem of air contaminants, especially inorganic elements from industrial plants, will be of continuing concern to us.

"The second event is the Arid Lands Conference at Albuquerque and Socorro, New Mexico, in the spring of 1955, under the sponsorship of the Southwestern Division of A.A.A.S. This conference was participated in by scientists from many countries and thus stimulated and focused a great deal on continuing area interest. Livestock production in the Western United States will benefit from the activities of both local and international groups concerned with arid land problems. A.A.A.S. will publish the proceedings of these conferences.

"The third event is the forthcoming conference on Atomic Energy and Agriculture to be held as a part of the A.A.A.S. meeting in Atlanta, Georgia, on December 26–31, 1955 under the leadership of C. L. Comar."

Reports on the activities of the Committee on the Intersociety Cooperation and the Scientific Manpower Commission were given by J. E. Foster:

"Meetings were held on December 18, 1953 and on April 23, and August 16, 1954; condensed summary reports of which were sent after each meeting to President A. E. Darlow and Director M. L. Baker. An annual report was also filed with the Secretary at the 1954 Executive Meeting.

"One of the achievements of the Committee on Intersociety Cooperation was the formation of the Policy Committee for Scientific Agricultural Societies, which officially came into existence on January 31, 1955 and to which your representative was elected. Through this organization we were able to secure representation on the Scientific Manpower Commission. Agriculture had not had a representative on this Commission and our American Society of Animal Production was not a member of A.I.B.S. Our own Director Marvel L. Baker was appointed to represent the Aminal Sciences and Dr. Truman E. Hienton (Head, Farm Electrification Section, Agricultural Engineering Research Branch, Agricultural Research Service U.S.D.A.) to represent Soils and Agricultural Engineering on the Scientific Manpower Commission. Director Baker could not attend some of the meetings of the Commission so when he accepted an assignment in Turkey in April 1955 your representative on Intersociety Cooperation, who had been attending the meetings in his place, was elected to fill his unexpired term which runs until December 31, 1956. At the last meeting of the Commission on November 11, Dr. C. L. W. Swanson of Connecticut was elected to succeed Dr. Hienton, whose term expires on December 31, 1955.

"The broad field of Agriculture has now had for the past year, for the first time, a voice in manpower problems of vital concern to the defense of this Nation. The following is taken from the Annual Report of the Executive Secretary of the Policy Committee for Scientific Agricultural Societies.

"*Review of Scientific Manpower Commission Activities*

"As in 1952–53, a major concern of the Scientific Manpower Commission (SMC) has been the military status of scientists. This concern extended to problems of deferment, utilization of scientific personnel in the armed forces, and legislation relative to selective service and reserve obligations. Although there has been no change in policy relative to scientists in uniform, the Commission has taken an active part in placing many inductees in the Specialized and Professional Personnel Program and in this effort has received excellent cooperation from the Army. Of greater importance is the revision of the Department of Defense policy. Upon the insistence of the Commission, the Office of the Defense Mobilization Committee on Specialized personnel has taken a review of the Specialized and Professional Personnel Program.

"Relations with the Selective Service System have improved during the past year. A year ago there was a heavy drain on graduate students, science teachers, and industrially employed scientists. Since January, Selective Service headquarters have ruled favorably upon 95 percent of the cases that the Commission has placed before it.

"The easing up of the situation is due to the fact that the military manpower pool has become quite large, plus the fact that present military requirements do not require more than one-half to two-thirds of our physically and mentally fit young men. Under these conditions, it is logical to expect that more serious attention will be given to the scientific and technological needs of the Nation.

"The 84th Congress was faced with the need of extending the regular draft and the doctors draft, both of which expired June 30. Arguments by the Executive Director of the SMC in support of an amendment restoring selectivity to the Selective Service System were ineffectual, but he did have some success in arriving at a shorter period of liability for scientists and engineers who had been deferred for professional work.

"It is hoped that the proposed National Reserve Plan bill will contain a provision whereby young men with scientific training may fulfill their military obligation by entering a six-months training program, and thereafter serving in the military reserve. Should this measure be enacted into law, the scientific manpower situation would be substantially improved. It would mean that young scientists and engineers serving in critical occupations and essential activities would be withdrawn from their work for six months instead of 24 months. It would reduce the drain on the specialized personnel in the military manpower pool by 75 percent.

Policy Committee

"The sum of $650.00 was contributed to the Scientific Manpower Commission as the Policy Committee's contribution toward the activities of the Commission in 1955.

"In the Policy Committee for Scientific Agricultural Societies, agricultural sci-

entists today have a body on a par with those in other areas, such as chemistry and biology. Prior to the organization of this committee, however, agricultural scientists lacked any sort of official body which might be called upon to consider national problems affecting their members.

"Today the member societies of PCSAS feel that they have an effective organizational setup, and thereby a means of taking under consideration with a minimum of effort and red tape any problem which concerns individual scientists or groups of scientists in the broad field of agriculture. It might be added that this committee, as it is now organized, will require practically no overhead operational costs.

"In conclusion I wish to state that it is the plan of the Commission, in so far as possible, in the event of another conflict or in the preparation for one, to avoid the apparent disregard for adaptability or training as has sometimes occurred in the past. A screening process is being developed for reserves as well as a constructive program for reserve officers and for those in service. We not only wish to be prepared in case of conflict but if possible prevent such conditions from occurring."

President Miller expressed the appreciation of the Society for the excellent work that has been done by J. E. Foster and M. L. Baker in connection with their respective special committees.

M. L. Baker, former President and Director, sent his greetings to the Society and best wishes for a successful meeting.

Activities of the Society with the Agricultural Research Institute were read by J. O. Grandstaff:

"The Agricultural Research Institute held its fourth annual meeting October 17 and 18 at the NAS-NRC Building, Washington, D. C. There were three half-day program sessions, one business session, and a banquet. Approximately 110 members and guests were in attendance.

"A comprehensive review of research progress on corn presented by industry, state and federal scientists was a special feature of this year's program. The topics discussed included economics and marketing, breeding, agronomic practices, and research contributing to better utilization of corn in animal and human nutrition, and for industrial uses, particularly the wet milling industry. The work of the Agricultural Board was discussed in the light of recommendations which ARI made to it last year. In response to previous recommendations by ARI, the Agricultural Board has established new committees for (1) Agricultural Pests, (2) Agricultural Equipment, and (3) Animal Physiology and Metabolic Diseases.

"The Project and Proposals Committee reported that more than 200 proposals had been submitted by representatives of Class A and Class B members of ARI for consideration in making recommendations to the Agricultural Board. Those of interest to standing committees of the Agricultural Board were referred to the appropriate committee for further study. Some of the proposals received were in the nature of research projects requiring financial support. Since these do not fit into the program of ARI or the Agricultural Board, the committee plans to distribute a list of these projects to research agencies. ARI also recommended that the Agricultural Board consider establishment of new committees in the areas of: (1)

Agroclimatology and Land and Water Use and Conservation, (2) Air Contaminants, (3) Crop Production, (4) Plant Characteristics including Physiology and Breeding, and (5) Soils.

"Under the sponsorship of ARI a conference on problems involved in the study, evaluation and application of pesticides with special reference to safety of use, was held in Washington, D. C., on November 19. Participating in the conference were representatives of the agricultural chemicals industry, State agricultural experiment stations, and Federal agencies.

"The ARI also sponsored an international conference on the use of antibiotics in agriculture, held in Washington, D. C., October 19–21. The subject-matter areas discussed were: (1) growth response in animals, (2) special biological problems, (3) mode of action, (4) crop usage, (5) food preservation, and (6) public health aspects. Complete proceedings of the conference should be available about April, 1956.

"Plans for next year include some expansion in scope of activities and the establishment of additional committees within ARI to consider three major problems which confront research administrators in industry and government: (1) Procedures for collecting and disseminating research information; (2) Encouragement of careers in sciences relating to agriculture; (3) Problems of cooperation among scientists in industry and State and Federal governments.

"At present the ARI has 57 Class A or paying members from industry. The Class B membership is made up of representatives from 38 agricultural experiment stations, 24 scientific societies, 21 government agencies, and 6 other organizations. This represents an increase of 14 Class A members and 11 Class B members compared with a year ago.

"Officers elected for next year are as follows:

President	Walter C. Dutton, Dow Chemical Co.
Vice President	M. T. Goebel, E. I. Du Pont Co.
Secretary	N. F. Kennedy, Corn Industry, Research Foundation

"It is recommended that the American Society of Animal Production continue its membership in the Agricultural Research Institute."

Dr. Ralph W. Phillips, who has served for several years as a special representative of the American Society of Animal Production to maintain liaison with the European Association of Animal Production, submitted the following report through the Secretary of the Society, and sent his regrets at being unable to attend the 1955 Meeting:

"The European Association for Animal Production now has as members national organizations representing 20 countries, namely: Austria, Belgium, Denmark, Finland, France, Germany, Iran, Israel, Italy, Luxembourg, Morocco, the Netherlands, Portugal, Spain, Switzerland, Tunisia, Turkey, United Kingdom and Yugoslavia. The Third General Assembly of the Association was held at Reading, England, on 13 July, 1955. The financial position of the Association has remained sound, all member organizations having paid their subscriptions, thus allowing the Association to meet its normal expenses and further increase the reserve fund.

"The Association continues to conduct its work primarily through the holding of study meetings and through small commissions set up to deal with various aspects of animal production.

"The fifth in the series of study meetings was held at Reading, England, from 6 to 13 July 1955, when the principal subject was Animal Production from Grass. Before the meeting commenced, an opportunity was afforded delegates to visit the Royal Show at Nottingham and a number of grassland farms and research institutes in other parts of the country. The two main papers at the study meeting were: Animal Management for Intensive Production from Grass by Professor M. M. Cooper, of King's College, University of Durham, at Newcastle-on-Tyne, United Kingdom; and Agronomic and Physiological Considerations governing Grassland Utilization by R. Dijkstra, Institute of Agricultural Economics, The Hague, Netherlands, and A. M. Frens, Director, State Agricultural Experiment Station, Hoorn, Netherlands. Short papers were also submitted on various aspects of the subject by a large number of delegates. The proceedings of this study meeting will be published by the Association.

"The Commissions, consisting in each case of workers prominent in their respective fields in the countries from which organizations are members of the Association, continued to give attention to a number of topics. Work has included the completion of compilation of information on pig progeny testing in the various countries; the possible standardization of methods of fodder analysis; the establishment of a method of expressing the protein requirements of domestic animals; the publication of a guide for carrying out comparative experiments in feeding; a revision of the Index of Agricultural Research Institutes in Europe together with an indication of their major research projects; further studies on the economic situation of horse breeding in Europe and the influence of farm mechanization; and a study on the progeny testing of beef cattle.

"The Association is also cooperating with FAO in the completion of a glossary of animal husbandry terms which it is hoped will eventually be available in four languages: English, French, German and Spanish. The Association has collaborated with FAO in holding the following meetings: (1) A meeting on the regulations concerning International Trade in Animal Semen, held at Cambridge, England, 22–25 March 1955; and (2) A meeting on Problems of Animal Feeding in Europe, held at Gottingen, Germany, 26–30 September 1955.

"The Association issued its fourth publication Production et Commercialisation de la Viande and collaborated with FAO in the production of FAO Development Paper No. 51, Problems of Animal Feeding in Europe, which was based on the papers and discussions of the 1953 Paris meeting on this subject.

"At the meeting of the Council of the Association held at Reading in July, it was agreed to undertake the following activities, apart from those indicated above, during the coming year: (a) The organization of the Seventh International Congress on Animal Production which will take place in Madrid from 23 May to 1 June, 1956; (b) to cooperate with FAO in the organization of a technical meeting on pig progeny testing in Denmark, November, 1956; (c) to hold a special meeting of the Pig Study Commission in Paris prior to the Madrid Congress; and (d) to continue their collaboration with FAO and the FAO European Committee on Agriculture, as well as other international organizations, on matters of European interest in the field of animal production. Particular attention is called to the

Seventh International Congress on Animal Production, since any members of the American Society of Animal Production who plan to be in Europe during the coming summer, may wish to attend. Information concerning the Congress may be obtained from Mr. K. Kallay, Secretary of the European Association for Animal Production, Via Quintino Sella 54, Rome, Italy."

Our representative on the Ralston Purina Award Committee, R. F. Cox, was not able to attend the meetings but reported by letter that three men had been selected for this award in animal husbandry, namely: Berl A. Koch, B.S., Iowa State College, M.S., Cornell University and studying now at the University of California; Theodore A. Long, B.S., M.S. from Oklahoma A & M College and continuing his graduate work at Oklahoma; and Donald P. Waldorf, B.S., Purdue University and presently located at the University of Wisconsin.

The Society wishes to express its appreciation to the Ralston Purina Company for encouraging graduate study and development of men by these Fellowship Awards.

At the request of T. S. Hamilton the Society stood for a minute in memory of the fine work and real contribution made to the Animal Science by the late R. W. Trullinger, former chief of the Office of Experiment Stations, Washington, D. C.

President Miller introduced the new officers for the Society for 1956: L. E. Casida, President; J. C. Miller, Vice-President; and W. M. Beeson, Secretary-Treasurer.

The meeting adjourned at 3:45 p.m.

Respectfully submitted,

W. M. BEESON, *Secretary-Treasurer*

MEMORIALS

Arwed C. Baltzer

A. C. "Ace" Baltzer, Secretary-Treasurer of Michigan Artificial Breeders Cooperative, died unexpectedly of a heart attack at his home in East Lansing, Michigan, February 1, 1955.

He was born in St. Louis, Missouri, April 7, 1894. He graduated from the University of Missouri in 1915 with a B.S. in Dairy Husbandry. He accepted a teaching position at the University of Idaho and remained there until September, 1917, when he enlisted in the Army during World War I and served with the Army of Occupation in the 126th Infantry Regiment, 32nd Division, attaining the rank of First Lieutenant. Following the war, he was appointed to the extension staff of Purdue University in 1919 where he served two years as dairy specialist before coming to Michigan State College.

He was married in 1922 to Virginia Reinhardt in St. Louis, Missouri. Mrs. Baltzer, a daughter, Betty V., and a son, Robert, all of East Lansing survive. Also surviving are three brothers and three sisters residing in Missouri, a brother in Houston, Texas, and a sister in Clyde, Ohio.

Outstanding in Baltzer's career as an extension dairyman are his dairy-alfalfa campaigns, development of a DHIA program, cooperative bull associations, and contribution to the artificial breeding cooperatives of Michigan. He also assisted in founding of the National Association of Artificial Breeders and the American Red Danish Cattle Association.

In August, 1949, Baltzer was a delegate from this country to the Twelfth International Dairy Congress held in Stockholm, Sweden. He also attended the Sixth World Grassland Congress in the Netherlands delivering a paper on artificial breeding.

Since 1940, his efforts have been devoted to artificial breeding. Under his leadership, the Michigan Artificial Breeders Cooperative provided service to farmers in 78 of the 83 counties in both peninsulas of the Wolverine State. These developments will stand as a Memorial to him.

George Arthur Brown

George Arthur Brown, Emeritus Professor of Animal Husbandry, Michigan State University, died on May 5, 1955. He was born in Omer, Michigan, May 13, 1886.

He was graduated from the then Michigan Agricultural College in 1907 and immediately joined his Alma Mater in charge of the livestock herds. He made steady and fast advancement in the animal husbandry department, becoming professor and head in 1919. In addition to his professional duties, for many years he operated his own livestock farm near East Lansing as a practical experiment. His entire life was devoted to the advancement of the interests of livestock producers and their families. He was constantly in demand as a speaker for livestock events because of his sound judgement, foresight, and practical slant on livestock problems.

In 1937, he was chosen as President of the American Society of Animal Production. He was author of over 50 bulletins and journal articles in adidtion to innumerable news releases on livestock subjects.

He was a member of East Lansing's Peoples Church, a life member and the first worshipful master of Lodge No. 480, F. & A.M., past patron of the Red Cedar Chapter No. 434, O.E.S., past president of Lansing Kiwanis Club, and member of the Farmers Club and M.S.U. Retiree's Club. His wife preceded him in death in 1952, and he is survived by four married daughters—all graduates of Michigan State University, 12 grandchildren, and a brother. He died in his sleep at his home probably due to a heart attack. He will be missed, but his devotion and contributions to the Michigan and National livestock industry will always be remembered.

Ralph Boyd Cathcart

Ralph Boyd Cathcart was born April 19, 1910 near Leavenworth, Kansas. He received his bachelor of science degree in agriculture at Kansas State in 1933 and his master of science degree from the University of Nebraska in 1934. He was employed with the Nebraska drouth relief office in 1934 and 1935 before joining the Kansas State extension staff as an assistant county agent in 1935. He was appointed an instructor in the animal husbandry department in 1936 and advanced to assistant professor in 1937 and to associate professor in 1948.

Cathcart was in charge of work with horses at Kansas State, and was prominent in organizations concerned with horses, being secretary of the Kansas Quarter Horse Association, and a director of the Kansas Saddle Horse Association. He served many years as superintendent of the horse division at the Hutchinson Kansas State Fair.

Professor Cathcart had been on leave during the 1951–1952 school year to do advanced work at the University of Minnesota. He completed his work and was to have received the Ph.D. degree within a few weeks of the date of his death. Upon recommendation of the staff of the Department of Animal Husbandry at the University of Minnesota, that institution conferred the Ph.D. degree upon Professor Cathcart post-obitum, March 17, 1955.

Cathcart was a member of Alpha Zeta, Phi Kappa Phi, and Gamma Sigma Delta honorary societies, and of the American Society of Animal Production.

From 1942 to 1946 he served as a lieutenant in the armed forces.

He died at the University of Kansas Medical Center in Kansas City, January 30, 1955.

Harry Sands Grindley

Harry Sands Grindley was born on a farm near Mahomet, Illinois April 13, 1864. He graduated from the University of Illinois in 1888; was assistant in the Agricultural Experiment Station, 1888–9; assistant in chemistry, 1889–92; and was a fellow at Harvard University, 1892–4, receiving the degree of Doctor of Science in 1894. He then returned to the department of chemistry, University of Illinois as an assistant and was promoted through the various ranks, being made a professor and director of the chemistry laboratory in 1904. From 1907 to 1911 he was professor of animal chemistry. In 1911 he was made professor of animal nutrition in the College of Agriculture and organized that Division. He then retired September 1, 1929 and died September 2, 1955.

He was the outstanding meat chemist of his day and was the first to show the

similarity in chemical composition and nutritive value between the cheaper and the more expensive cuts of beef.

With Isabel Bevier, he studied the effects of different methods of cooking upon the chemical composition and nutritive value of meat. Our present methods of meat cookery are based upon these researches. He also studied the effects of cold storage, including freezing, upon the nutritive value of meat and poultry.

He conducted elaborate experiments in human nutrition involving 24 men for a period of 220 days, and was the first to show that saltpeter as used in curing meats had no detrimental effects upon humans.

He conducted many digestion and metabolism experiments with cattle, hogs, and sheep which contributed greatly to our present knowledge of the requirements of these animals. He was among the first to measure the differences in the nutritive value of proteins from different sources due to differences in their amino-acid content.

In 1913, he and H. H. Mitchell introduced the use of statistical methods in the interpretation of experimental results, one of the first applications of statistics to agricultural research in this country.

He was an early member of the American Society of Animal Nutrition which later became the American Society of Animal Production.

Heman Lauritz Ibsen

Heman Lauritz Ibsen, professor emeritus of genetics in the department of animal husbandry of Kansas State College, died January 28, 1955 at his home following a long illness.

Dr. Ibsen was a member of the Kansas State College faculty for 35 years, beginning his service July 1, 1919 and retiring July 1, 1954. He was an internationally recognized authority on inheritance of characteristics in livestock. He presented papers at meetings of the International Congress of Genetics at Stockholm, Sweden in 1948; Edinburgh, Scotland in 1939; and Ithaca, New York in 1932. The author of a textbook in genetics, he had numerous pamphlets and articles published in scientific journals.

Doctor Ibsen was born September 16, 1886 in Chicago, Illinois and his early education was in the Chicago public schools. He received his B.S., M.S., and Ph.D. degrees from the University of Wisconsin. During World War I he served with the chemical warfare service. His church membership was with the Unitarian church of Madison, Wisconsin.

Membership in professional societies included the American Society of Animal Production, the American Dairy Science Association, The American Society of Zoologists and the American Genetic Association. An avid reader, Doctor Ibsen was considered an authority on classical literature and had a private library of more than 4,000 volumes in addition to a large scientific library in his own field.

Frank Thorp, Jr.

Frank Thorp, Jr., 54, professor of animal pathology, College of Veterinary Medicine, Michigan State University, East Lansing, died on September 9, 1955, of bulbar poliomyelitis in a hospital at Denver, Colorado.

Dr. Thorp was born in Panora, Iowa, in 1900, received his D.V.M. degree at Iowa State College in 1926 and his Ph.D. at the University of Illinois in 1936. He devoted his entire tremendous energy to research in animal diseases, particularly those of sheep and swine. He had served on the veterinary staffs at the University of Illinois, Colorado A. & M. College and, since 1940, at Michigan State College, where his assignment was primarily on experiment station work. He was author or co-author of approximately 100 technical articles and bulletins on nutritional diseases, listeriosis, hyperkeratosis, and other diseases.

Dr. Thorp was a member of the AVMA, Research Workers in Animal Diseases of North America, Society of American Bacteriologists, Society of Experimental Biology and Medicine, the American Association of Pathologists and Bacteriologists, American Society of Animal Production, and of six honorary societies.

He is survived by his widow, a son, and a daughter.

His devotion to the advancement of animal disease control and knowledge will always be remembered by his colleagues and friends of the National and Michigan animal industries.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN AND SPECIAL ASSIGNMENTS FOR 1956

Standing Committees

Committee on Research.....G. Bohstedt
Committee on Monograph.....C. E. Terrill
Committee on Extension.....R. M. McWilliams
Committee on Membership.....J. C. Miller
Committee on Teaching.....Doyle Chambers

Special Committees

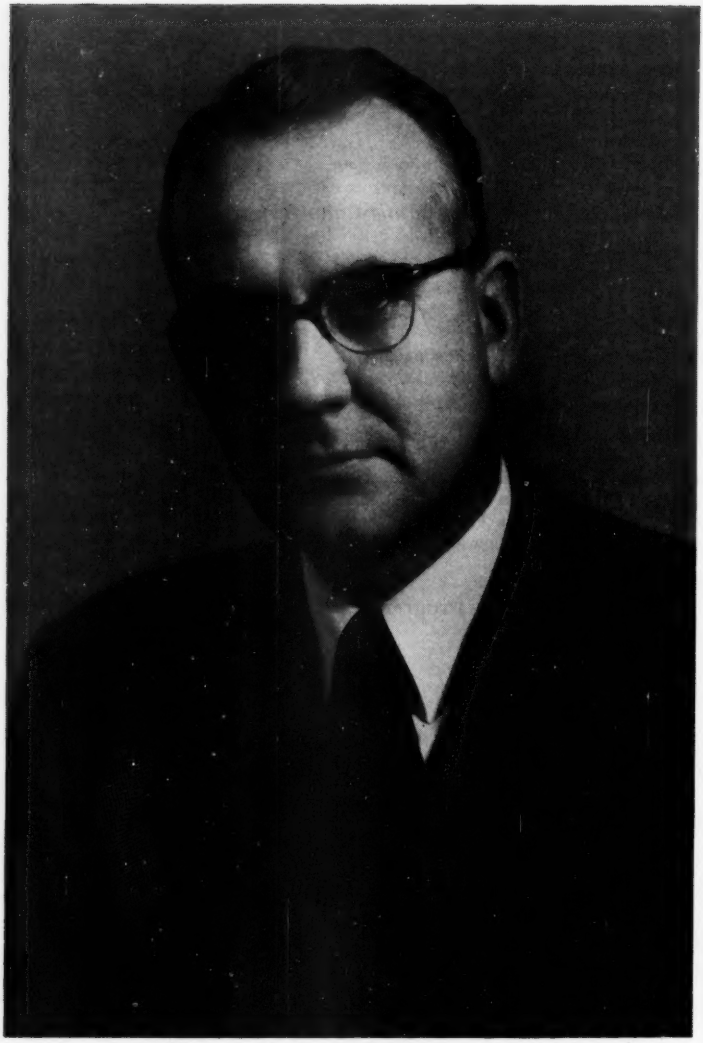
Committee on Information.....Carl F. Neumann
Committee on Necrology.....G. S. Bratcher
Committee on Nominations.....A. E. Darlow
Committee on Morrison Award.....J. C. Miller
Committee on American Feed Manufacturers Award.....E. R. Barrick
Committee on Registration and Facilities.....T. W. Perry

Program Committees

Breeding and Genetics.....R. C. Carter
Extension.....R. M. McWilliams
Meats.....T. N. Blumer
Nutrition.....S. L. Hansard
Pastures and Forages.....D. M. Baird
Physiology.....E. L. Wiggins

Special Representatives

American Association for Advancement of Science Council....T. C. Byerly
Committee on Intersociety Cooperation and Scientific Manpower Commission ..... J. E. Foster
Division of Biology and Agriculture, National Research Council and Agricultural Research Institute.....J. O. Grandstaff
European Association for Animal Production.....R. W. Phillips
Ralston Purina Award Committee.....R. F. Cox



L. E. HANSON

L. E. Hanson was awarded the eighth Feed Manufacturers Association Award which was presented during the 47th Annual Meeting of the American Society of Animal Production in Chicago on November 26, 1955.

AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD
1955

The recipient of the 1955 AFMA Award in Animal Nutrition is an industrious research worker, a capable teacher and a popular speaker. He has developed extensive contacts with the hog producers, feed manufacturers and the personnel of the marketing and packing interests. His research in the field of swine nutrition has covered a very broad scope, including studies on brood sow reproduction and lactation, development of starter and creep rations for baby pigs and work on arsenicals, antibiotics, fiber, protein levels, distillers solubles, and vitamins for growing-finishing swine.

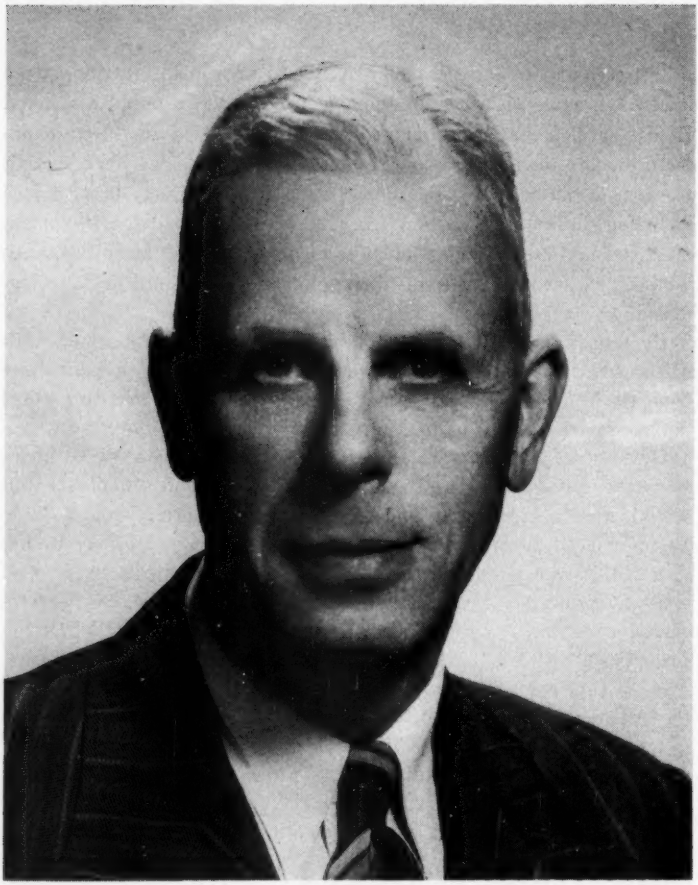
He was born at Willmar, Minnesota, attended the School of Agriculture at Morris, Minnesota, then received a B.S. degree in Agriculture from the University of Minnesota in 1936. Cornell University granted him a Master's degree in 1937 and a Ph.D. degree in 1940.

He was an American-Scandinavian Foundation fellow in Denmark from the fall of 1937 to the summer of 1938, and except for this period, was an assistant in animal husbandry at Cornell from 1936 to 1940. In 1940, he went to the University of Nebraska to take leadership in the swine work and was successively advanced from the rank of assistant professor to associate and then professor. He has been in charge of swine nutrition research at the University of Minnesota since 1950.

He is a member of several scientific societies, including Sigma Xi and the American Society of Animal Production. He was elected to the Senate of the University of Minnesota in 1954 (an advisory group of senior members of the faculty) and is a member of the Feed Survey Committee of the AFMA.

A demonstration which he conducted entitled, "Forty years of progress in swine feeding" drew international attention in 1953 by spotlighting the tremendous advances in this field. The report was widely used in local and national publications.

It's my privilege to present to you Dr. L. E. Hanson, the recipient of the 1955 AFMA Award in Animal Nutrition!



E. W. CRAMPTON

E. W. Crampton received the tenth Morrison Award which was presented during the 47th Annual Meeting of the American Society of Animal Production in Chicago on November 26, 1955.

THE MORRISON AWARD
1955

Earle Wilcox Crampton was born in Middletown, Connecticut in 1895. He received the B.S. degree from Connecticut Agricultural College in 1919, the M.S. from Iowa State College in 1922, and the Ph.D. from Cornell University in 1937. He has been a member of the staff of Macdonald College, McGill University since 1922 being Professor of Nutrition since 1941.

His contribution to the livestock industry is attested to by over 100 publications in the scientific literature. This work has dealt primarily with swine nutrition, nutritional value of pasture herbage and other feeds, chemical methods of assessing feeding value, digestibility techniques and evaluation of digestion coefficients, and experimental designs for feeding trials. During more recent years, his attention has been devoted to a study of the requirements of baby pigs weaned at an abnormally young age, and he has published the formula of a highly successful dry ration for pigs of this age, along with recommended management practices.

Research designed to study the usefulness of the apparent digestion coefficient as a tool in feed evaluation has led him to many fundamental observations. Beginning with the use of markers in pig digestibility studies, and continuing through the successful use of inert index materials in digestion trials with different species, his current research in this field is pointed towards studies of the effect of ration composition on the apparent digestibility of its nutrient components.

He is a fellow of the Royal Society of Canada, the Chemical Institute of Canada and the Agricultural Institute of Canada. He is well known to the American Society of Animal Production being the first recipient of its American Feed Manufacturers Association Award in 1948 and its president in 1951.

NEWS AND NOTES

Applications for the Ralston-Purina research fellowships should be on file by March 1. Application blanks may be obtained from the Ralston-Purina Research Awards Committee in care of Mr. J. D. Sykes, Ralston-Purina Co., St. Louis, Missouri. The fellowships are for $1,560 annually and awards will be made in the fields of nutrition and physiology research as applied to dairy, poultry and animal husbandry, and in research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agriculture College and approved Veterinary College are eligible.

The joint annual meeting of the Western Section of the American Society of Animal Production and the Western Division of the American Dairy Science Association will be held at the University of Nevada, Reno, July 15–18, 1956.

Copies of the Proceedings of the annual meeting of the Western Section of the American Society of Animal Production are available as follows:

Volume	Year	Price
3	1952	$1.00
5	1954	$1.26
6	1955	$1.00

These may be obtained from J. F. Kidwell, Animal Husbandry Department, University of Nevada, Reno.

Paul G. Homeyer was in Mexico the fall quarter of 1955 as argicultural statistician with the Food and Agriculture Organization, United Nations. He returned to his position in the Statistical Laboratory, Iowa State College, in December. His assignment had as its primary intent, advising the Government of Mexico on methods of experimental design, including associated survey techniques, and their application to problems in agricultural investigations.

J. D. Mankin was appointed Extension Animal Husbandman at the University of Nevada, effective December 15, 1955. He replaced Lyle O. McCartney, who resigned to engage in cattle ranching near Elko, Nevada. Mr. Mankin received a Bachelor of Science degree in Animal Husbandry at New Mexico State College, and a Master of Science degree in Animal Breeding at Colorado A. & M. He has been in charge of the Volkman Angus herd at Selma, California, for the past year.

The Second World Congress on Fertility and Sterility will be held May 18 to 26, 1956 in Naples, Italy.

T. C. Byerly, formerly Chief of the Animal and Poultry Husbandry Research Branch, was appointed assistant director of Livestock Research in the Agricultural Research Service, U.S.D.A., on September 16. N. R. Ellis was named to succeed Dr. Byerly as Chief of the Animal and Poultry Husbandry Research Branch.

E. C. Elting has been named Deputy Administrator for Experiment Stations in U.S.D.A.'s Agricultural Research Service. In addition to representing the Administrator in all relations with the State experiment stations, Dr. Elting has supervision of the State Experiment Stations Division and the Territorial Experiment Stations Division.

R. W. Trullinger, former Assisant Administrator of the Agricultural Research Service for Experiment Stations, died on November 8 at Doctors Hospital, Washington, D. C., following a prolonged illness. Dr. Trullinger served 43 years in the Department of Agriculture and was Chief of the Office of Experiment Stations from 1946 until reorganization of the Department in 1953, when he became Assistant Administrator.

Joseph Kastelic, former Professor of Animal Husbandry at Iowa State College, was appointed Professor of Animal Nutrition at the University of Illinois on January 1 to fill the position vacated by Dr. T. S. Hamilton, now Associate Director of the Experiment Station.

C. M. Kincaid, former Professor of Animal Husbandry at the Virginia Polytechnic Institute, has been appointed Regional Coordinator for the Southern Regional Beef Cattle Breeding Project, with headquarters at Knoxville, Tennessee. In this position he succeeds E. J. Warwick, now head of the Beef Cattle Research Section, Animal and Poultry Husbandry Research Branch, Beltsville, Maryland.

Leigh T. Giltner, who served U.S.D.A. for 48 years as veterinarian and administrator of animal disease research, died at his home in Washington, D. C., on November 23, 1955.

George E. Holm, who retired on September 1 from the Dairy Husbandry Research Branch of the Agricultural Research Service, U.S.D.A., died from a heart attack on November 16, 1955.

Herbert L. Chapman, who completed his Ph.D. degree at Iowa State College in June 1955, has been appointed assistant animal nutritionist at the Everglades Station, Belle Glade, Florida.

A recent bulletin by Binet, Leslie, Weiner and Anderson entitled, "Analysis of Confounded Factorial Experiments in Single Replications," N. C. Agr. Exp. Sta. Tech. Bul. No. 113, Institute of Statistics, Reprint Series No. 70, 1955, pp. 64, $1.00, should be helpful to researchers in planning and analyzing factorial experiments.

Glen Hall received his Ph.D. degree in Animal Nutrition at Iowa State College in June 1955 and is now an associate animal husbandman at the University of Tennessee.

John W. A. Brant, formerly Agricultural Officer of the Food and Agriculture Organization of the United Nations (1953–55), now Specialist of the Universidad de Guayaquil y Universidad de Idaho en Programa Cooperative para el Progreso de las Ciencias Agropecuarias, has been honored by nomination to Profesor, Facultad de Agronomia y Veterinaria during a Sesion Solemne de la Facultad de Agronomia y Veterinaria, Universidad de Guayaquil, Guayaquil, Ecuador—octogesimo octavo Aniversario de su Fundacion. He has launched a research program in poultry nutrition, which is to be continued concurrently with research programs in animal physiology and genetics.

George E. Short has joined the veterinary division of the Norwich Pharmacal Co., Norwich, N. Y. Formerly he taught diagnostics and did research work at Oklahoma A & M College.

The second edition of the book, Range Management, by L. A. Stoddart and A. D. Smith was recently published by McGraw-Hill Book Co. The two chapters devoted to problems of the nutrition and general management of beef cattle and sheep under range conditions should be of especial interest to those in livestock production. The book presents a concise summary of the important aspects of range management and conservation problems.

Charles A. Lassiter has resigned his position in the Dairy Section at the University of Kentucky to accept a similar position at Michigan State University.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, doubled-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. J. K. Loosli, Department of Animal Husbandry, Cornell University, Ithaca, New York, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. W. M. Beeson, Department of Animal Husbandry, Purdue University, Lafayette, Ind., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.